METALLURGIA

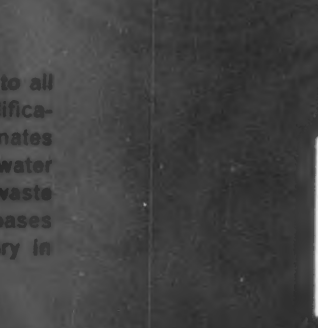
THE BRITISH JOURNAL OF METALS

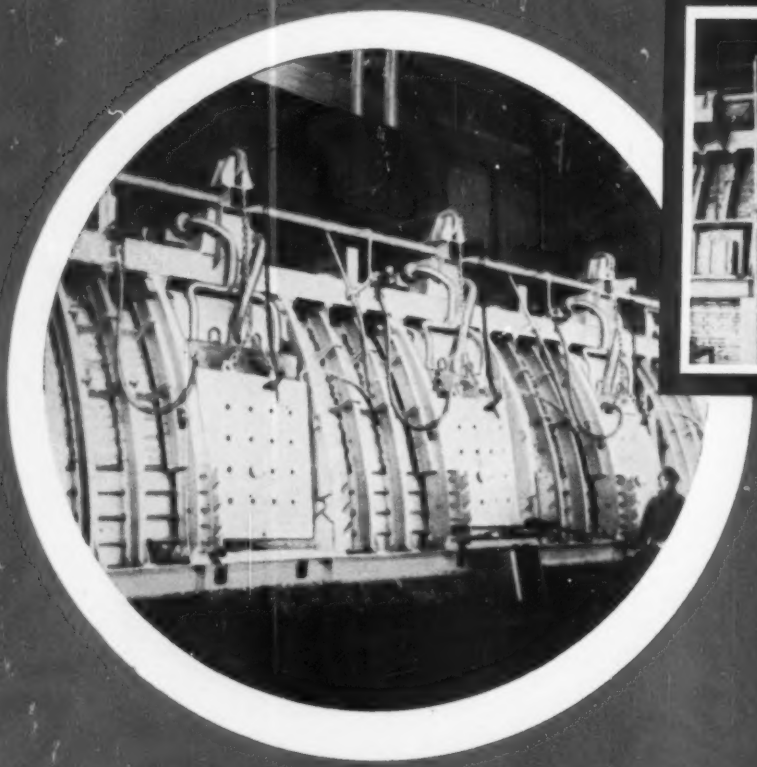
Vol. 63 No. 375 JANUARY, 1961 Monthly: Two Shillings and Sixpence

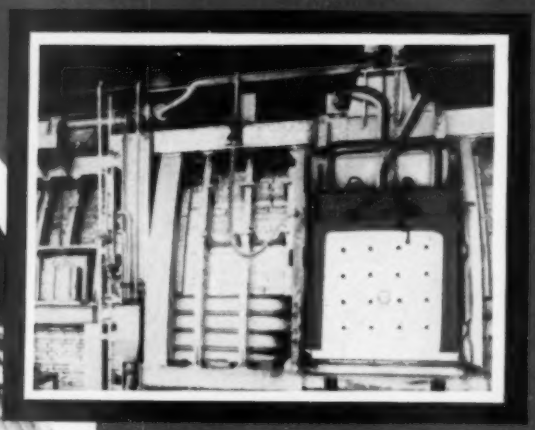
Reining Hot Cooling

exclusively applied by S & A
increases open hearth furnace efficiency

An evaporative cooling system that can be applied to all types of Open Hearth furnaces without need for modification. Working by the Thermo-syphon principle, it eliminates the need for circulating pumps, reduces cooling water requirements to the furnaces by 50%, reclaims more waste heat, considerably extends the life of door frames, increases furnace availability and will show a capital recovery in approximately 12 months.







As a result of collaboration between Reining and Maerz standardized outside dimensions have been established for both conventional frames & Reining Hot-Cooling frames.

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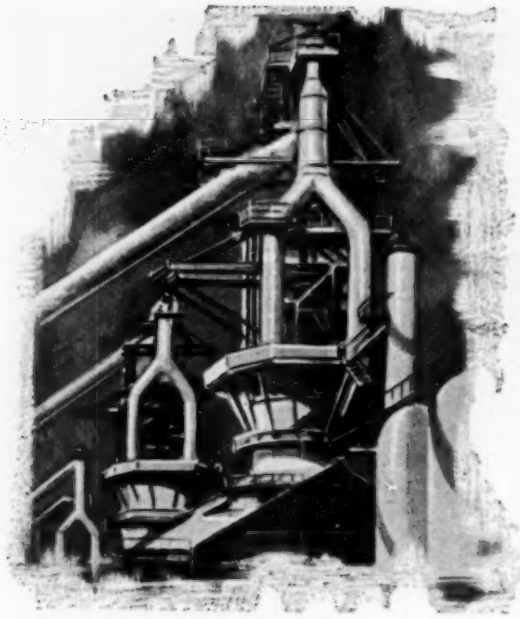
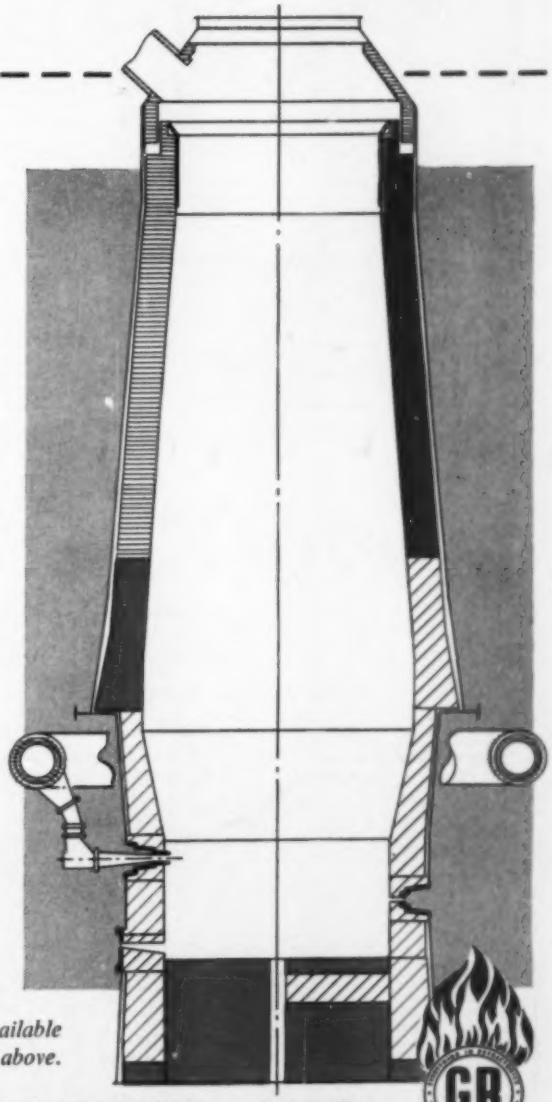
FURNACE ENGINEERS



'GR'
BLAST FURNACE REFRACTORIES



NUMAX
A new dense, high fired refractory to meet the most exacting conditions encountered in the stack in modern furnace operations. Main features of this refractory are very low porosity, high resistance to abrasion and a very low iron content which makes for complete immunity from carbon monoxide attack.

SILLMAX 'I'
A 100% bondless Sillimanite refractory of highest purity and low porosity for use in the lower stack, bosh and hearth. Very resistant to slag and alkali attack and volume stable at the highest temperatures likely to be encountered in the blast furnace.

FOSTER HIGH GRADE 'S'
An improved quality stack refractory with a high abrasion resistance and resistant to carbon monoxide.

FOSTER CROWN 'S'
An improved quality 42% Alumina refractory for use in the lower stack, bosh and hearth.

FOSTER CARBON
A well-tried and proved refractory for use in hearth, well and bosh. Can be supplied in either large blocks or standard sized bricks.

INSULATION
A complete range of G.R. Amberlite insulating material is available.

Suitable jointing cements and ramming compositions are available for use with the various blast furnace refractories described above.

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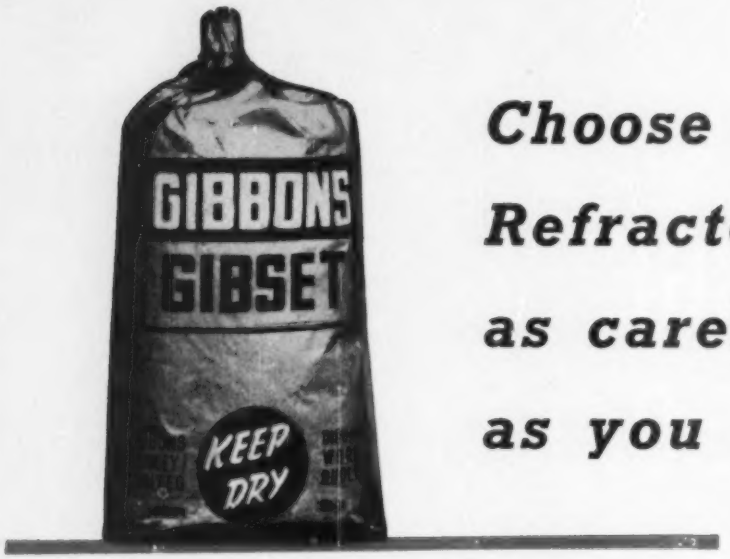
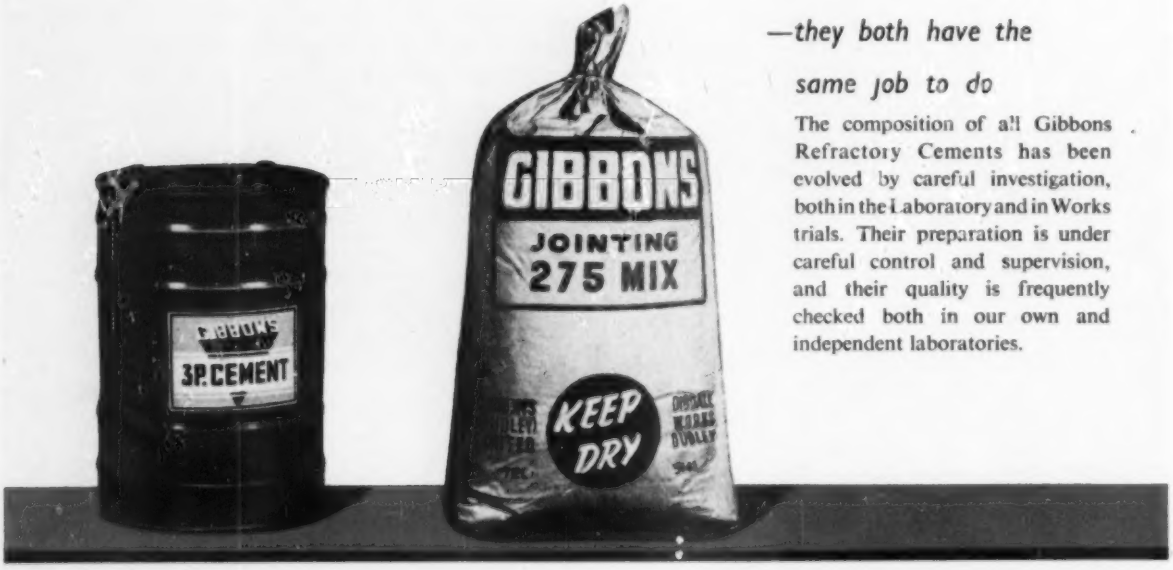
440



Choose your Refractory Cements as carefully as you choose your bricks



—they both have the same job to do

The composition of all Gibbons Refractory Cements has been evolved by careful investigation, both in the Laboratory and in Works trials. Their preparation is under careful control and supervision, and their quality is frequently checked both in our own and independent laboratories.

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Refractory and Insulating Refractory Concretes · Firebrick and Insulating Firebrick Aggregates

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100 TON ALL BASIC
OIL FIRED OPEN HEARTH FURNACE

Installed at The Albion Steel Works of
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This O.H. Furnace is providing consistently
high outputs on cold charged material
with excellent overall economy.

Priest Furnaces Ltd.

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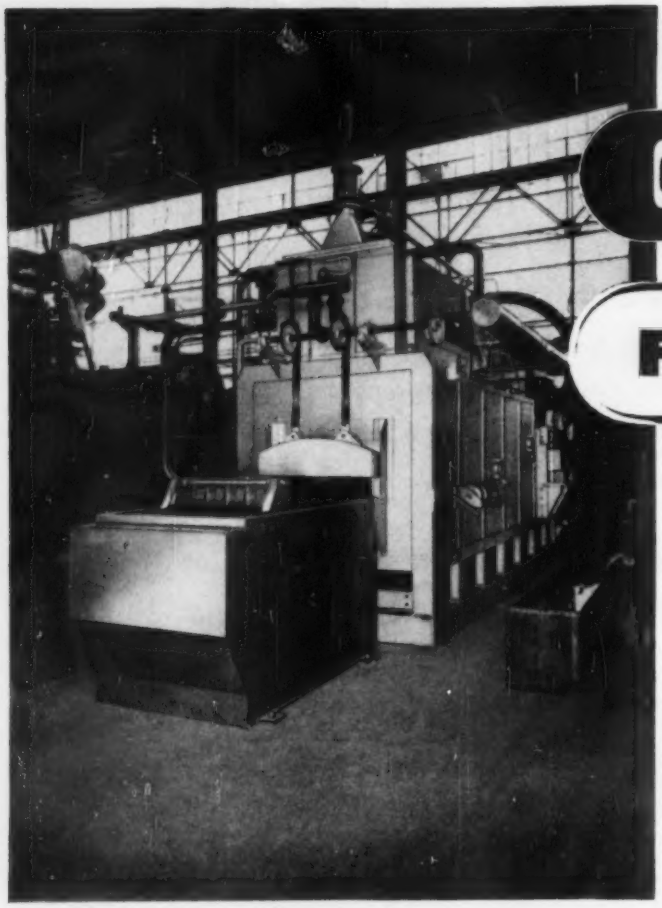
FI52



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Patent Nos. 637,337. 646,691. 606,401.

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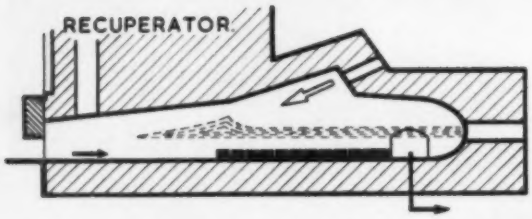

PRO-TEK Continuous Billet Heating Furnaces are built under licence arrangements with Metallurgical Oxygen Processes Limited and Indugas, G.m.b.H., Essen.
Specially suitable for repetition work either mild steel or alloys.
Standard sizes from 10 cwts. per hour upwards with guaranteed performance and scale free high quality finish heating.

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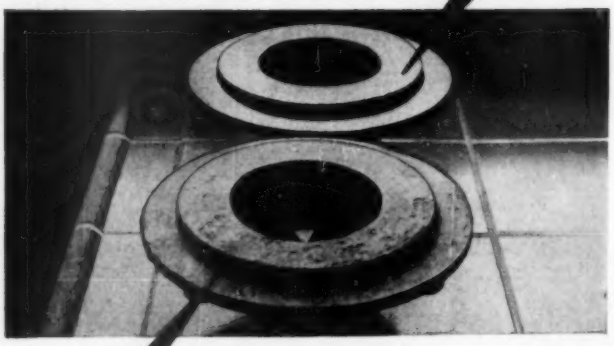

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G105

must be good

A hardened steel roll must be good to give the precision, the finish, the long service required in cold rolling; so good that virtually only a handful have mastered this most exacting branch of the forgemaster's craft. Doncasters are proud to be amongst that number.

Doncasters hardened steel rolls are made in the widest variety of sizes from the small rolls used for precision metals to rolls weighing several tons each.

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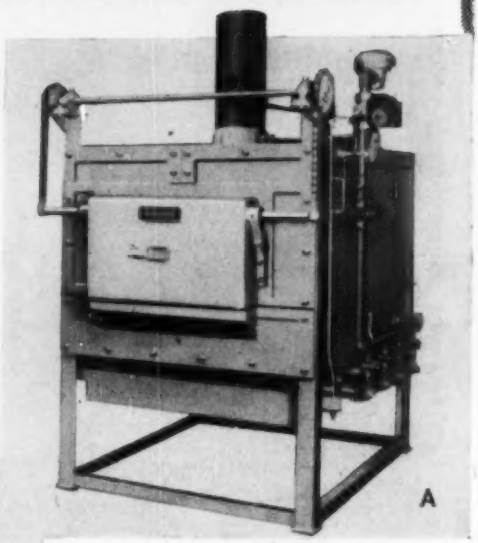
R33

NEW STANDARDS
in tool room heat treatment

Brayshaw Engineers and Technicians are constantly engaged in an intensive research and product development programme designed to maintain our leadership in the manufacture of new furnace equipment of proven dependability and accuracy in widely diverse applications. The products illustrated are just a few examples from our extensive range.
If you would like information on these or any other part of our range please write to us for further details.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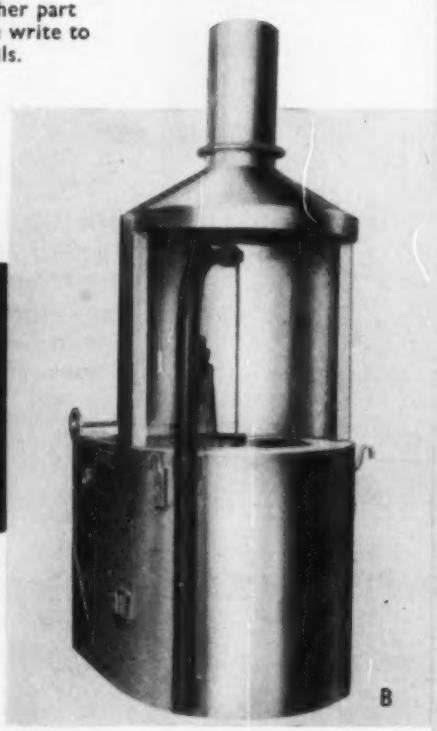
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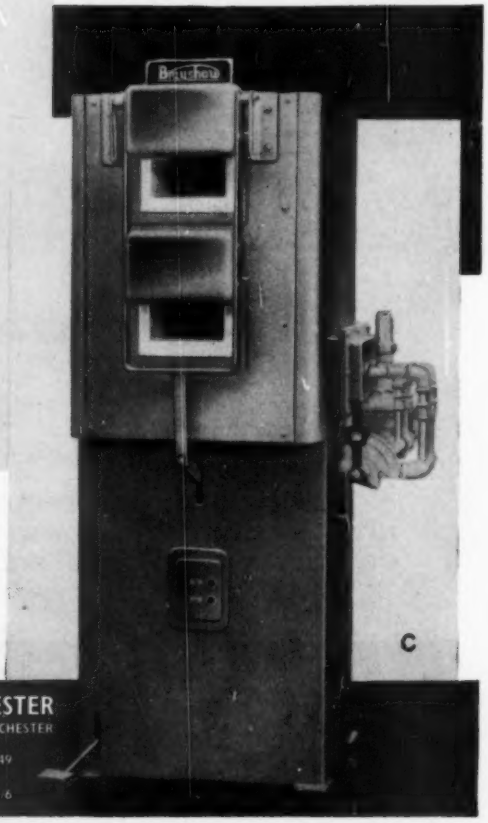

C

What the illustrations show:

A.—'Hynor' Oven Furnace.
B.—Liquid Bath Furnace.
C.—Twin Chambered High Speed Steel Furnace.

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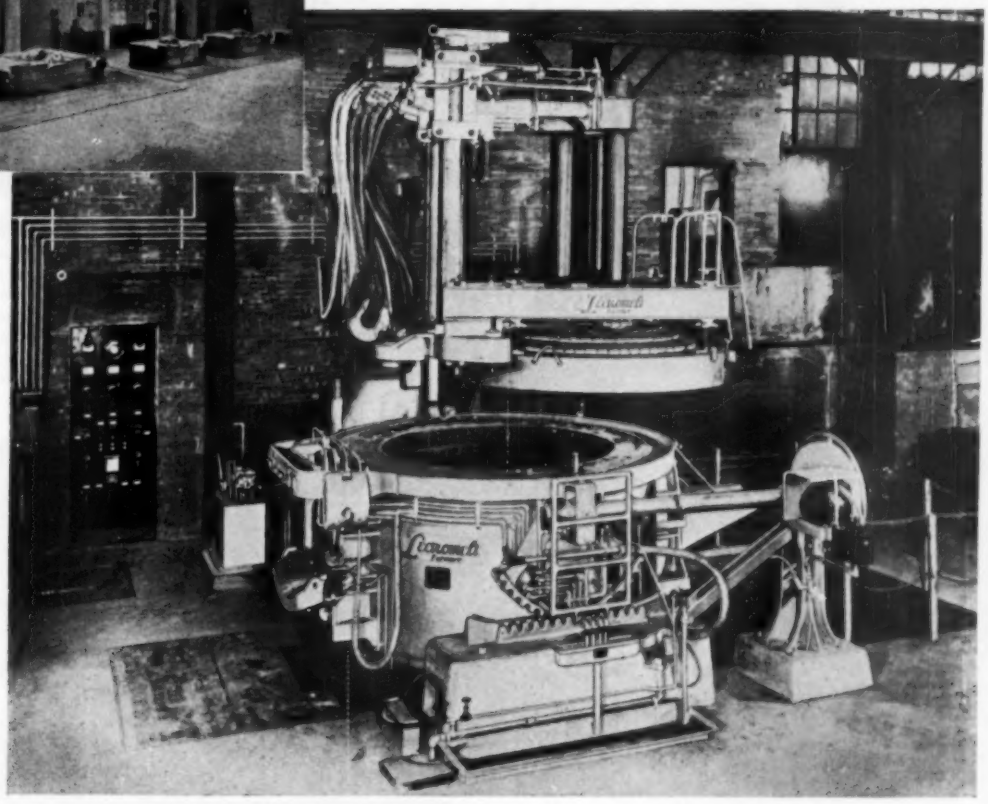
GWB

DEMAG Lectromelt



Demag high-frequency induction furnace installation at a steel making plant, incorporating two 1 ton capacity furnaces, two 660 lb. capacity furnaces, and one 110 lb. capacity furnace.

A 3 ton capacity Lectromelt arc furnace of 9' 0" diameter shown with roof swung ready for charging.

High Speed and High Output are the key features in the medium and smaller range of furnaces offered by G.W.B. Furnaces Ltd. Many years are behind both the Coreless and Arc Furnaces of Demag and Lectromelt designs.

Daily, electric furnaces are finding wider and wider applications, and the coreless induction (crucible) type is no exception as it is an ideal medium for melting steel and iron, and all other metals. It is particularly advantageous in steel works where a charge of scrap of known analysis is melted and is an installation that pays for itself in a very short time. The proven economies of operation of electric arc furnaces offered by G.W.B. have earned an enviable reputation, and a few of their outstanding features are:—

Separately mounted roof lift and swing mechanism for top charging; Four point roof suspension of the roof ring; Electrode holders of the power operated, spring-held, air release type; High speed movement of the electrodes; Offset rocker centres to return furnace from extreme tilt in event of power failure.

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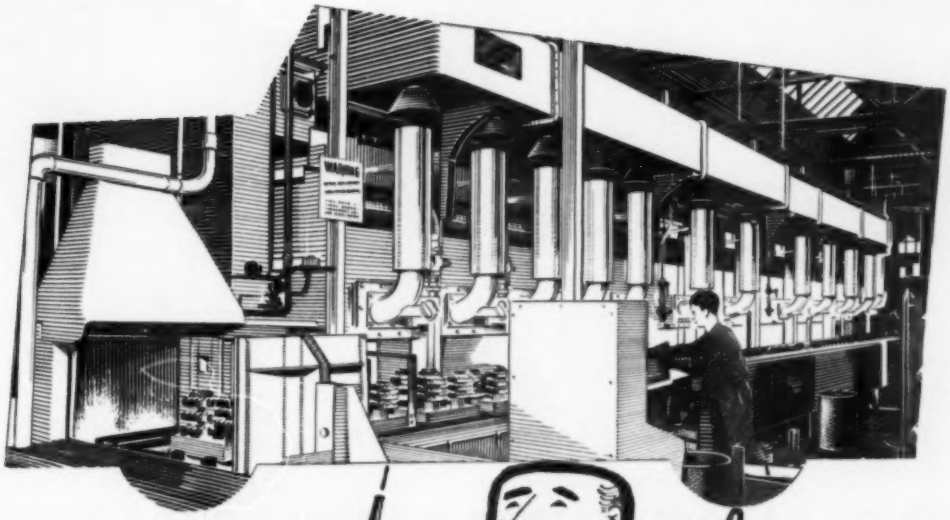
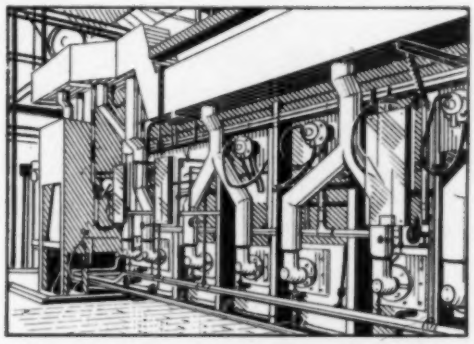
GWB 243

PROPAGAS PROPANE



carries weight in the Motor Industry



These illustrations, by courtesy of Ford Motor Co. Ltd, show two of many continuous gas carburizing furnaces installed at their Dagenham factory, using endothermic atmospheres produced from PROPAGAS.

PROPAGAS provides industry not only with a high calorific value fuel gas (approximately 2,500 b.t.u. cubic foot) but also with an excellent medium for the production of special furnace atmospheres. It is widely used for gas carburizing, carbonitriding and bright annealing of ferrous and non-ferrous metals.

BOTTOGAS Butane, like Propagas, is a petroleum gas delivered and stored as a liquid under moderate pressure. Bottogas is used as a fuel for fork lift trucks and for many other specialised applications.

PROPAGAS Propane and **BOTTOGAS Butane** come from the great British refineries of the Shell and BP Groups, backed by a technical service second to none and with a complete sales organisation covering the United Kingdom.

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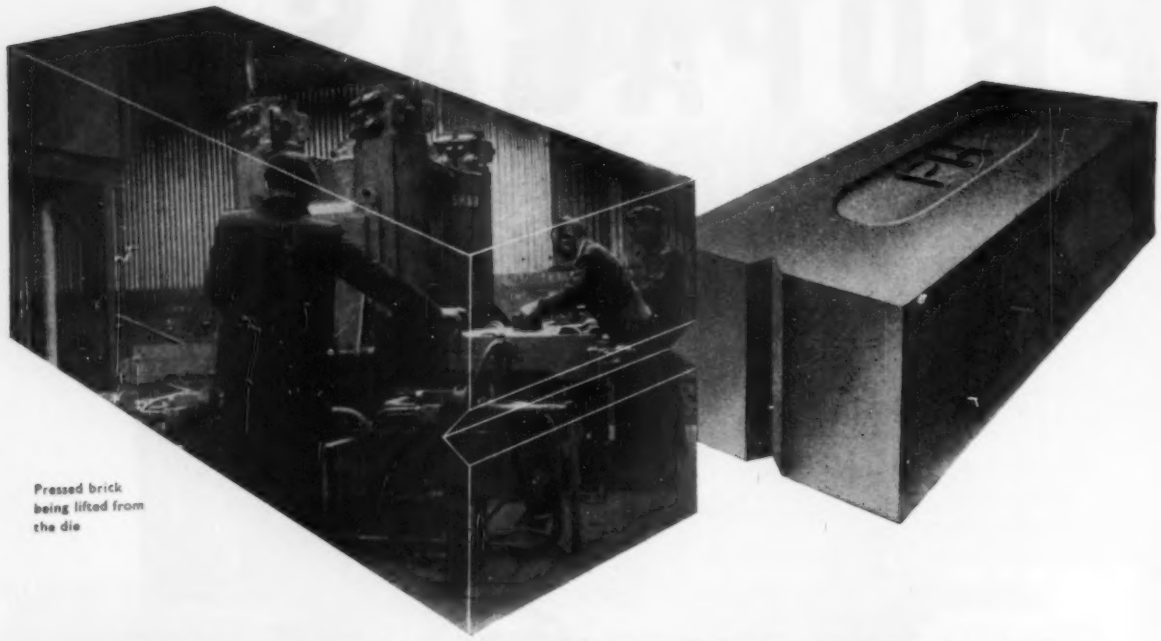

Pressed brick being lifted from the die

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Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.

PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

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The result of continuous research and development into the problems of higher temperatures, longer life, greater resistance to abrasion and improved production control techniques enable Dyson Diamond D Ladle Bricks to remain continuously abreast of the demand for better refractory material for the Steel Industry.

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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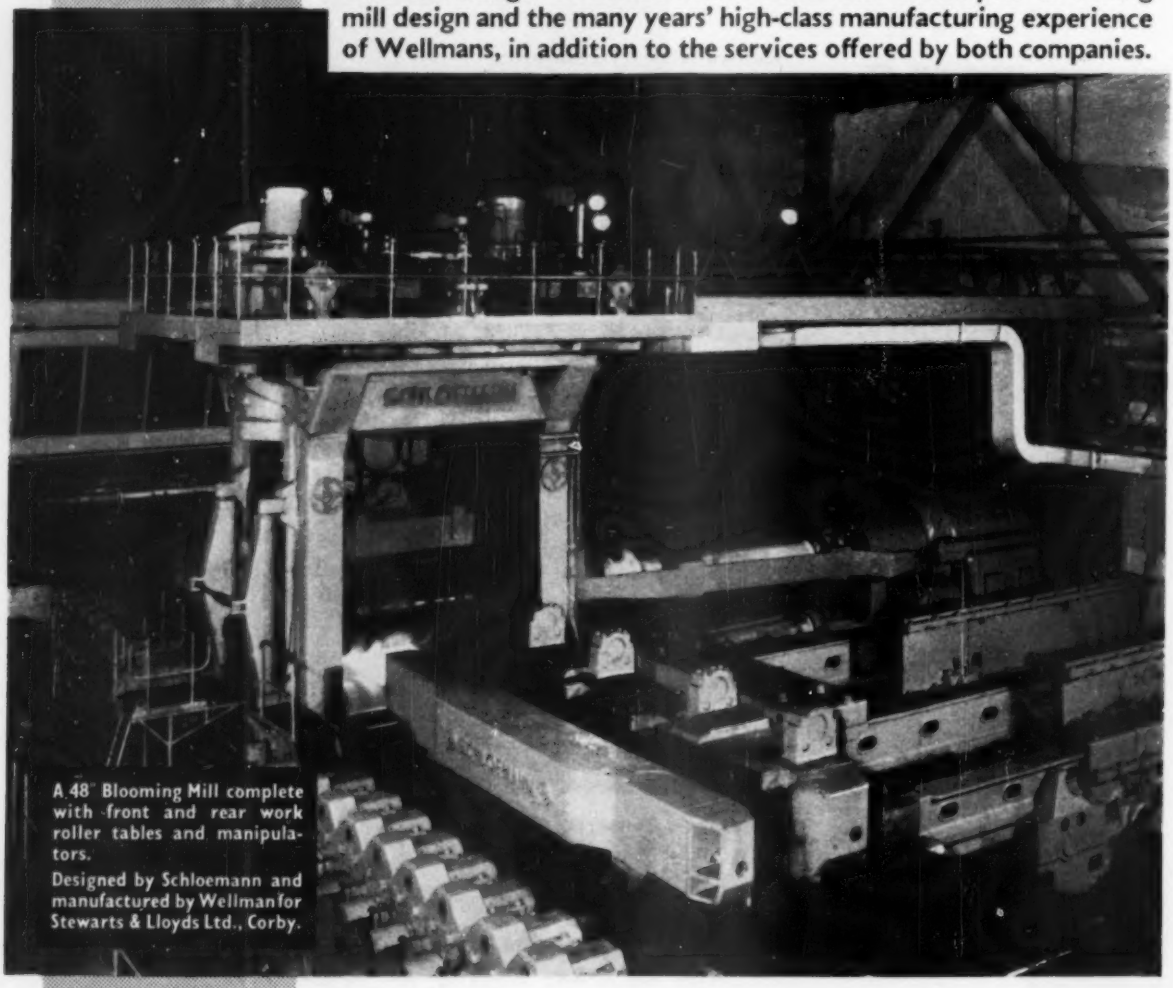
Schloemann AG., Düsseldorf, and The Wellman Smith Owen Engineering Corporation Ltd., London, have concluded an agreement, under the terms of which the two firms are to collaborate in the construction of hot and cold rolling mills, for ferrous and non-ferrous metals, in Britain and the Commonwealth countries. Steelworks in these territories will therefore be able to take advantage of Schloemann's advanced techniques in rolling mill design and the many years' high-class manufacturing experience of Wellmans, in addition to the services offered by both companies.



A 48" Blooming Mill complete with front and rear work roller tables and manipulators.

Designed by Schloemann and manufactured by Wellman for Stewarts & Lloyds Ltd., Corby.

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JANUARY, 1961 Vol. LXIII. No. 375

Record Nickel Consumption

THE days of "black market" nickel at £3,000 a ton are past, and instead of sharing out the available supplies, producers are now striving to expand established markets for the metal and set up new ones, so that the new production units coming into operation will be fully employed. The year 1960 saw a new record set for consumption of nickel by the free world with a figure exceeding 500 million pounds—an increase of 15% above that for 1959—but it is estimated that before the end of 1961 the total nickel production capacity of the free world, exclusive of Cuban sources, will approach 600 million pounds annually. These figures were given by Mr. Henry S. Wingate, chairman of the board of directors of The International Nickel Company of Canada, Limited, in a year-end review of the nickel industry. The main factor contributing to the record consumption in 1960 was the substantial increase in the use of nickel in Europe, in contrast to North America, where large inventory liquidations by consumers of steel products held back the production of stainless and nickel alloy steels during the second half of the year, thus limiting nickel consumption to the 1959 figure. The geographical distribution of the free world's consumption of nickel over the past twelve months has been estimated as: Europe, 43·5%; U.S.A., 43%; Canada, 2·5%; and others, 11%.

A study of the consumption of nickel by end products shows that its use in stainless steels has made the greatest advance, and now accounts for approximately one-third of the total. A substantial increase was also registered for the application of nickel in electroplating—which represents 16% of the total consumption—mainly as a result of the use by the automotive industry of improved techniques, permitting higher quality nickel plating. Other major uses of the metal include high-nickel alloys (15%), nickel alloy steels (13%) and iron and steel castings (12%), whilst copper and brass products take up 4% and other uses 8%.

As already stated, production capacity will approach 600 million pounds a year by the end of 1961, of which total Canada will account for more than three-quarters. International Nickel's new project at Thompson, Manitoba—the world's first fully integrated nickel producing operation—will have an annual capacity of 75 million pounds, second only to Inco's facilities in the Sudbury district of Ontario. This will bring Inco's capacity to more than 385 million pounds a year. In addition, Falconbridge Nickel Mines, Ltd., and Sherritt Gordon Mines, Ltd., will contribute 65 million and 25 million pounds, respectively. The planned capacity of the French nickel company, Société Le Nickel, has been estimated at 55 million pounds a year, and United States annual capacity (mainly The Hanna Mining Company, Riddle, Oregon) remains at 23 million pounds. There remains the capacity of Japanese refiners, which, given sufficient ore, could produce some 35 million pounds a year. No account has been taken of Cuban production facilities, including the 100 million pounds a year plant built by the United States Government, as it is not possible to predict how soon there will be a resumption of nickel supply for the free world from these sources.

During the period of nickel shortage, considerable research and development work was carried out in order to find ways and means of using less nickel in steels and other alloys. Now, with a production capacity exceeding demand, the operation has had to go into reverse, and the efforts of the nickel producers have once again been directed towards an expansion of the use of the metal. Intensified research, market development, sales promotion and technical services have contributed to the increased nickel consumption in 1960 in the face of strong competition from other materials.

Typical of these efforts was a series of illustrated lectures and comprehensive exhibitions on stainless steel held in important architectural centres of six major countries of Western Europe. In the same field, International Nickel, Atlas Steels, Ltd., and Union Carbide Canada, Ltd., co-operated with the National Industrial Design Council of Canada in organising an international exhibition of photographs of design in stainless steel which attracted entries from all over the world. A "Gleam of Stainless Steel" consumer product promotion in the United States and Canada, and a similar programme in the United Kingdom had as their object an increasing use of stainless steel in domestic equipment. Still in the stainless steel field, Inco has made an analysis of present and future markets for this material in the United States by consuming industries and the geographical location of these industries.

Chromium plating is trying to live down the unenviable reputation it acquired as a result of the inferior quality coatings produced since the war due to an unsatisfactory nickel undercoating. This was usually too thin, whether as a result of nickel shortage or of cheeseparing to keep down the price. Efforts are now being made to strengthen public preference for quality nickel-chromium plating, with an adequate underlay of nickel, and many automobile and appliance manufacturers have increased their thickness specifications for nickel plating.

Aluminium alloys have recently been used for holding liquefied gases because of the superior properties at low temperatures compared with mild steel. A new nickel alloy steel, developed by Inco for use at very low temperatures, was recently demonstrated in a technical testing programme called "Operation Cryogenics." This alloy steel is expected to find widespread use throughout industry for the storage and transportation of liquefied gases at temperatures as low as −320° F. (−195° C.).

Other market development and research activities

carried out on a world-wide basis during 1960 by International Nickel included work on such important nickel-consuming fields as alloys for high temperature applications, nickel alloy steels, foundry products, copper-nickel alloys, aluminium alloys, electronics, and chemical engineering.

Mr. Wingate concluded with a look at the future and expressed his optimism as follows: "In spite of the slowness in industrial pick-up in the United States, free world consumption of nickel will again be at a very high level in 1961. Spurred on by intensified market and research activities, and supported by increasing supplies of the metal, industry throughout the world will be receptive to using nickel in an expanding variety of applications. The economic and technological advantages which nickel can provide should result in the free world nickel consumption reaching new peaks in the years ahead."

Meeting Diary

2nd February

Institute of Metals, London Local Section. "The Development of Some New Bearing Materials," by P. G. FORRESTER. 17 Belgrave Square, London, S.W.1. 6.30 p.m.

5th February

Institute of Metals, Oxford Local Section. "New Aspects of the Electron Theory of Metals," by V. HEINE. Cadena Cafe, Cornmarket Street, Oxford. 7.15 p.m.

6th February

Institute of British Foundrymen, Sheffield Branch. "Some Practical Experiences in Making Moulds in a Mechanised Foundry," by H. PINCHIN. Technical College, Pond Street, Sheffield. 7 p.m.

7th February

Institute of Metals, South Wales Local Section. "Inspection of the High Strength Wrought Aluminium Alloys," by W. SMITHAM. Metallurgy Dept., University College, Singleton Park, Swansea. 6.30 p.m.

Leeds Metallurgical Society. "Metals in Antiquity," by R. F. TYLECOTE. Metropole Hotel, Leeds. 6.30 p.m.

Sheffield Metallurgical Association, Analysis Group. "Ion Exchange—Its Development, Significance and Use for Ferrous Analysis," by V. E. GRIPP. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

Society of Chemical Industry, Corrosion Group. Short Papers Evening. Engineering Centre, Stephenson Place, Birmingham. 7 p.m.

8th February

Manchester Metallurgical Society. "Residual Stress and Stress Relieving," by L. E. BENSON. The Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

9th February

East Midlands Metallurgical Society. "The Modern Production and Metallurgy of Blackheart Malleable Cast Iron," by H. GREATOREX. Derby and District College of Art. 7.30 p.m.

Institute of British Foundrymen, London Branch (Beds. and Herts. Section). "Effect of Mould Materials on the Cooling Rate and Physical Properties of Cast Metals. (Sub-Committee report T.S.46)," by J. HIRD. At W. H. Allen, Sons and Co., Ltd., Bedford. 7.30 p.m.

Liverpool Metallurgical Society. "The Origin and Solution of Some Industrial Corrosion Problems," by E. C. CAMPBELL. Department of Metallurgy, The University of Liverpool, Liverpool, 3. 7 p.m.

13th February

Institute of Metals, Scottish Local Section. "Beryllium as a Structural Material," by A. J. MARTIN. 39 Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

14th February

Institute of British Foundrymen, London Branch (Slough Section). "Developments in Melting and Casting," by W. W. GLICK. Lecture Theatre, High Duty Alloys Limited, Slough. 7.30 p.m.

Sheffield Metallurgical Association. "Some Factors Affecting Impact Properties," by P. W. Bygate. BISRA Laboratories Hoyle Street, Sheffield, 3. 7 p.m.

Society of Chemical Industry. "The Occurrence of Fireside Corrosion in Modern Steam Generators," by W. D. JARVIS and D. B. LEASON. Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. 6 p.m.

16th February

Institute of Metals, Birmingham Local Section. "The Growth and Prospects of the Aluminium Industry," by G. W. LACEY. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

North East Metallurgical Society. "Plastics versus Metals," by P. T. MOORE and H. HUGHES. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.30 p.m.

20th February

Institute of British Foundrymen, London Branch (East Anglian Section). "Developments in the Production of Gunmetal Castings," by F. HUDSON. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

21st February

Sheffield Metallurgical Association, Refractories Group. "Some Aspects of Basic Refractories," by J. OWEN. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7.30 p.m.

West of England Metallurgical Society. "Metallurgy in Modern Jewellery," by MISS DOROTHY PILE. The College of Technology, Ashley Down, Bristol, 7. 7.30 p.m.

22nd February

Institute of British Foundrymen, London Branch. "Production and Applications of Spheroidal-Graphite Iron Castings in a General Engineering Firm," by H. TURNER and P. SAVAGE. Constitutional Club, Northumberland Avenue, London, W.C.2. 7.30 p.m.

Manchester Metallurgical Society. "Metallurgical Applications of Radioisotopes," by M. C. INMAN. The Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

24th February

West of Scotland Iron and Steel Institute, Joint Meeting with Iron and Steel Institute Engineers' Group. "Layout and Design of a Hot Strip Mill," by M. F. DOWDING, C. STURDY and A. A. THOMAS. 39 Elmbank Crescent, Glasgow. 6.45 p.m.

28th February

Sheffield Metallurgical Association, Joint Meeting with Institute of Metals, Sheffield Local Section. "Martensite Formation" by PROF. W. S. OWEN. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

Society of Chemical Industry. Cathodic Protection Panel Meeting. "External Protection of Floating Craft" (two items) by M. G. DUFF and P. CLARK, respectively. Society of Chemical Industry, 14 Belgrave Square, S.W.1. 6 p.m.

SAMUEL OSBORN & CO., LTD., Sheffield, have opened a new warehouse at 7, Millfields Road, Bilston, where stocks of tool steels, engineers' small tools and files will be maintained for the convenience of customers in the Birmingham and Midlands area.

FENTER MACHINE TOOLS, LTD., 184, Aston Road, Birmingham, 6, have been appointed sole agents in the United Kingdom for material testing machines made by Losenhausenwerk Düsseldorf Maschinenbau A.G.

THE TUNGSTEN MANUFACTURING CO. (1958), LTD., announce that they have completed their removal of factory and offices to new premises at Brighton, Sussex and that their telephone number is now Hove 46281.

The Mechanism of Stress-Corrosion in a High-Purity Aluminium-Zinc-Magnesium Alloy

By E. N. Pugh*, B.Sc., Ph.D. and W. R. D. Jones†, D.Sc.

A marked similarity has been observed between deformation occurring during tensile and stress-corrosion tests on an aged aluminium–5·5% zinc–2·5% magnesium alloy. In both cases, plastic deformation is concentrated in the precipitate-free zones at grain boundaries, and results in stress-concentrations at associated grain-boundary triple points. These stresses are relieved normally by deformation in neighbouring grains but in the fully-aged alloy this is limited by the high hardness of the grains. The increasing stress-concentration then causes the production of a crack at a grain boundary adjoining a triple point. A theory of stress-corrosion failure is suggested, based on this mechanism of crack-initiation.

THE stress-corrosion of aluminium-zinc-magnesium alloys has been investigated extensively in recent years, but there have been few attempts to study the mechanism of failure in these alloys. A notable contribution to the understanding of the problem was made by Dix,[1] who attributed the failure to the preferential grain-boundary precipitation which occurs in these alloys during ageing, and to the fact that the precipitate is anodic to both the solid solution within the grains and the zone of depleted solid solution surrounding the grain-boundary precipitate. He suggested that, in a corrosive environment, the particles of precipitate are rapidly dissolved by electrolytic attack, thus producing a weakened network on the surface. A high enduring tensile stress would then tend to cause the material to fracture through the zones of depleted solid solution along a line joining the holes where the precipitate had been. While this mechanism has been generally accepted, it may be argued that it is essentially a theory of intercrystalline corrosion rather than one of stress-corrosion failure.

In view of the information now available on the mechanically-weak zones of solid solution at grain boundaries in the aged material, which may be either depleted in solute atoms[2,3] or precipitate-free,[4] and on the intergranular brittleness associated with the presence of this zone,[3,4] it is surprising that a more detailed mechanism of stress-corrosion has not been suggested which takes account of the mechanical aspect of the problem. Perryman[5] has commented on this and has pointed out that the effect of stress without corrosion has been neglected in stress-corrosion investigations.

The surface deformation occurring during tensile and stress-corrosion tests on a high-purity alloy is described in the present paper, and a mechanism of stress-corrosion is suggested which could account for these observations.

Experimental

The experiments were carried out on an alloy containing 5·5% zinc and 2·5% magnesium, a composition which, with respect to zinc and magnesium, is typical of commercial aluminium-zinc-magnesium alloys. The charge of high-purity materials was melted in a graphite crucible and teemed into a slab mould which was coated with graphite.‡ The slab was homogenised for 15 hours at 450° C. and then hot rolled at 420–440° C. to a final thickness of 0·066 in. (16 S.W.G.).

Specimens for tensile and for stress-corrosion tests were taken from the rolled sheet in a direction perpendicular to that of rolling. The stress-corrosion test pieces were produced from blanks, 7·5 in. × 1·0 in., which were reduced to 7·5 in. × 0·75 in., by milling equal amounts from both long sides; a centre portion, 2·0 in. long, was then reduced to a width of 0·5 in., using a high-speed milling cutter. After machining, the specimens were solution treated for 3 hours at 465° C. and quenched into cold water. This solution treatment temperature is that used for commercial aluminium-zinc-magnesium alloys. In the high-purity alloys the treatment resulted in complete solution of zinc and magnesium, and produced large equiaxial grains (4 grains/sq. mm.). Tensile specimens were tested in both the quenched condition and after ageing for 45 hours at 120° C. Stress-corrosion specimens were tested in the fully-aged condition only, as it was found that they were resistant to stress-corrosion when in the as-quenched state. The ageing temperature of 120° C. was chosen as earlier work had indicated that it produced a high susceptibility to stress-corrosion in commercial aluminium-zinc-magnesium alloys.[6] Ageing for 45 hours at this temperature produced maximum hardness (175 D.P.N.) of the alloy. In this condition, only grain-boundary precipitation was observed. Before testing, the gauge lengths of the specimens were polished electrolytically using a perchloric acid–ethyl alcohol solution. It was found that a satisfactory polish could be obtained over the entire gauge length, although slight pitting could not be avoided. The pitting, which was uniformly distributed across the gauge lengths, is not thought to have influenced the tests to any significant degree.

Tensile tests were carried out with a Hounsfield Tensometer. The deformation markings developed during the test were observed by means of a microscope mounted above the gauge length. The specimens were also examined after failure. In the stress-corrosion tests, a bending moment was employed to provide the stress, the specimens being supported at each end and subjected

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‡ Analysis indicated that the alloy contained less than 0·01% each of iron and silicon.

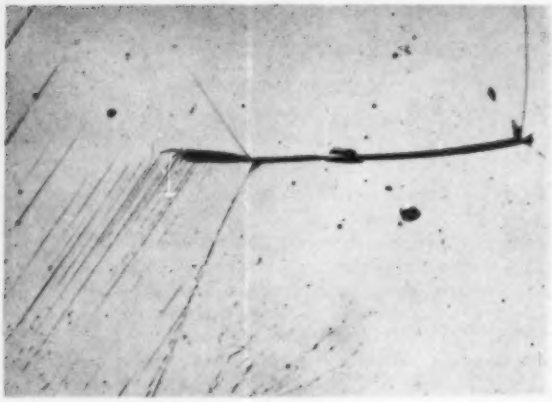

Fig. 1.—Tensile deformation at a grain boundary in the fully-aged material. ×150

to two-point loading across their gauge lengths. The loads, which were applied by means of a lever system, were calculated from a well-known formula for elastic deformation and, throughout the tests, a stress of 75% of the 0·1% proof stress was employed. The tests were conducted in a closed room in which the relative-humidity was approximately 87%. Under these conditions, the air itself provided a satisfactory corrosive environment* so that it was not necessary to immerse the specimens in any solution. The average life of specimens tested in this way was 8 days. During this period, the specimens were removed from the jig at frequent intervals and examined under a microscope. Specimens showed no trace of visible corrosion and, to demonstrate that the failures were in fact due to stress-corrosion, protective currents of 0·1 A. were applied to some specimens during testing. These specimens remained unbroken for 100 days, after which the tests were discontinued.

Surface Deformation during Tensile Tests

The majority of specimens were tested in the fully-aged condition. In this state, the material was extremely brittle, the ultimate tensile strength being 28·2 tons/sq. in. and the elongation 2%. When the elastic limit was exceeded, slip bands appeared on the polished surface; they were not distributed uniformly but were confined to a small region of the gauge length. Fracture, which occurred shortly after the appearance of slip bands, was intercrystalline and took place so suddenly that even at low rates of stressing it was not possible to detect the initiation of the crack. When specimens were examined after failure, fracture was found to have occurred in the region containing slip bands. Several grain-boundaries within this region were dark and well-defined, and often, at triple points, appeared to continue into the adjacent grains. Such a boundary is shown in Fig. 1. In some cases, particularly near the fracture, grain-boundary fissures were found at triple points. An example of this is shown in Figs. 2 and 3.

Studies have been made also of specimens in the quenched state. These specimens were tested within 24 hours of quenching so that very little hardening had occurred—the hardness being approximately 90 D.P.N. In this case, deformation occurred uniformly over the gauge length. During the early stages of the tests, grain-boundaries were observed to become dark and well-defined; the darkening at grain-boundaries was again found to extend into the grains at triple points and was associated with slip within the grains. When failure occurred, it was transcrystalline.

These observations are consistent with the mechanism of tensile failure proposed by Varley *et al.*,[3] who suggested that deformation is concentrated in the mechanically weak zones of solid solution at grain boundaries, and that rupture occurs through these soft regions. These observations permit a more detailed picture to be drawn. The darkening at favourably oriented grain boundaries indicates that deformation is concentrated in these regions and it appears that this sets up stress-concentrations at the associated triple points. These stress-concentrations are relieved to a certain extent, depending on the hardness of the alloy, by deformation within the neighbouring grains; this is revealed as surface folding extending into the grains at triple points. In the fully-aged material, the relief of stress-concentration is

* This was obtained by open exposure in the room of tanks containing a circulating solution of 3% common salt.

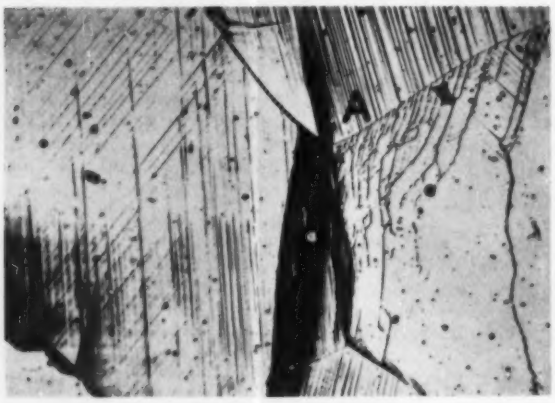

Fig. 2.—Tensile deformation near fracture in the fully-aged material. ×75

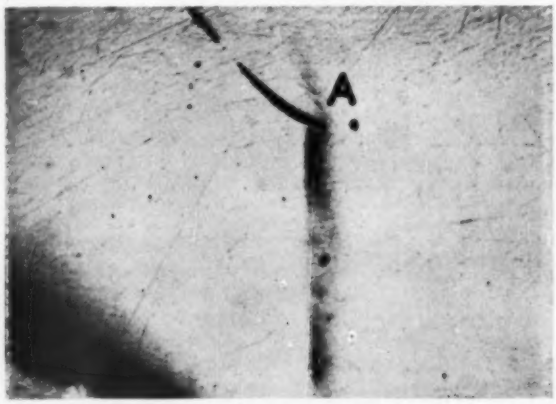

Fig. 3.—Field shown in Fig. 2. after light repolishing, showing a crack at triple point A. ×75

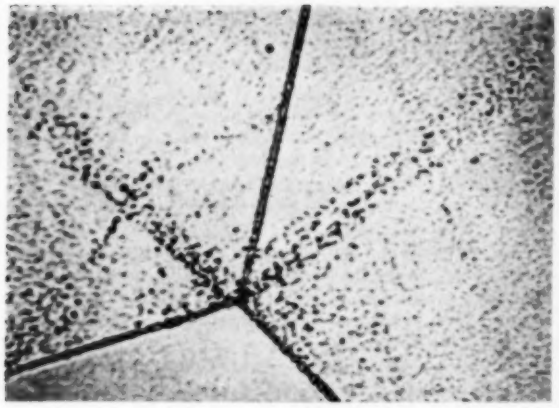

Fig. 4.—Precipitation at a triple point in a specimen aged 1,000 hours at 120° C. ×150

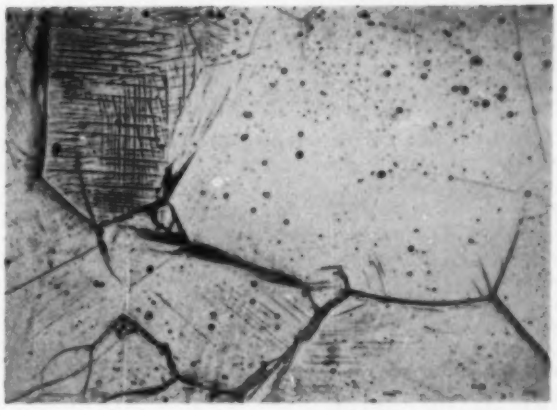

Fig. 5.—Grain-boundary deformation in stress-corrosion specimen of fully-aged material after testing 3 days. ×75

limited, so that the stress increases in magnitude until the cohesive strength of the grain-boundary region is exceeded and a crack is initiated. The crack then propagates through the grain-boundary zones. Failure to detect the cracks in their early stages indicates that propagation is rapid. In specimens in the quenched condition, the soft grains allow the stress-concentrations to be relieved continuously and in this case failure is not intercrystalline. Thus, failure in this alloy may be either intercrystalline or transcrystalline depending on the difference in strength between the grains and the precipitate-free zones at grain boundaries.

A similar mechanism for the initiation of intercrystalline cracks at triple points has been suggested by Chang and Grant,[7] who have studied deformation occurring during creep tests on aluminium-zinc alloys. The similarity between the deformation in these creep tests and in the tensile tests on the ternary alloy at room temperature supports the view that the observed deformation in the latter is due to preferential deformation in the grain-boundary zones. A related effect, observed in the aged alloy, is that precipitation appeared to occur along the extensions of certain grain boundaries into the neighbouring grains (Fig. 4). This effect has been reported by other workers,[8] and Perryman[5] has suggested that it is a result of grain-boundary slip that occurred during quenching. In the light of the above mechanism, it appears more likely that the effect originates in the deformation which occurs during ageing. Stresses set up by quenching and by the ageing process cause deformation in the grain-boundary zones and hence produce deformation at triple points. These deformed regions act as sites for precipitation during further ageing.

Surface Deformation during Stress-Corrosion Tests

Within a short period (24 hours) of loading the fully-aged specimens, several dark and well-defined intercrystalline paths became visible on the polished surface, indicating that deformation had occurred in these regions. At this stage, these paths, which were perpendicular to the stress-axis, extended over 2–3 grains and were accompanied by faint traces of slip in the neighbouring grains. As the tests continued, deformation at one, or sometimes two, of these paths increased in intensity while the remaining paths did not develop further. The active paths grew in length until they extended over 10–15 grains and, at the same time, the deformation along these paths became more severe. Fig. 5 illustrates part of a typical active path in a specimen tested for 3 days. At some of the triple points in the active path, deformation at grain boundaries extended into the adjoining grains.

It must be emphasised that the active paths illustrated in Figs. 5 and 6 were produced by surface rumpling, and that they did not contain cracks. Further, it was never possible to detect cracks along any active paths before fracture. Failure occurred after an average of 8 days along an intercrystalline path which contained the active path. When specimens were examined after failure, it was found that deformation in the grains near fracture was slight in regions which did not lie along the active paths.

The similarity between the deformation occurring in stress-corrosion and tensile tests suggests that the mechanism for the initiation of the intercrystalline crack is essentially the same in both cases. It is thought that the

Fig. 6.—Grain-boundary deformation in stress-corrosion specimen of fully-aged material after testing 6 days. ×75

mechanism described below, which takes this fact into account, explains satisfactorily stress-corrosion failure in this alloy.

Mechanism of Stress-Corrosion Failure

Dix's original theory[1] postulated that preferential grain-boundary precipitation causes corrosion crevices to be produced at the grain boundaries, and that stress-concentrations develop at the extremities of these crevices. The present work indicates that these stresses cause plastic deformation in the zones of precipitate-free solid solution. There is growing evidence that deformed metals are anodic with respect to undeformed metals,[9,10] so that the plastically deformed grain-boundary regions can be expected to become the sites of increased corrosive attack. It has also been suggested that plastic deformation ruptures the protective film on the surface of aluminium alloys and that this produces accelerated corrosive attack[11]; this would be an additional factor producing increased localised corrosion. The accelerated corrosive attack at the deformed regions produces fresh stress-concentrations which are relieved by further deformation in the grain-boundary zones. Thus cycles of corrosion and deformation occur at deformation paths.

Several deformed intercrystalline regions are formed initially, but deformation at one, presumably because of its favourable position i.e. relative orientation of the grain boundaries in the region of the deformation, causes the others to become inactive; further deformation is then concentrated at the one path. Corrosion crevices near the extremities of the active path create stress-concentration which is relieved by plastic deformation in adjoining, previously undeformed precipitate-free zones. These newly-deformed regions immediately become the sites of corrosive attack so that fresh stress-concentrations are produced, which cause further propagation of the active path. Increasing grain-boundary deformation results in stress-concentrations at triple points in the active path. The degree to which these stresses are relieved by plastic deformation in neighbouring grains is limited in the fully-aged material so that a crack is eventually initiated at a grain boundary adjoining one of the triple points. The crack then propagates through the weak grain-boundary zones until fracture occurs. Failure to detect the crack before fracture indicates that propagation is rapid. This is supported by the observation that crack propagation through the region which did not contain the active path was associated with very small amounts of plastic deformation. The rapid propagation of the crack in the present instance is due to the coarse grain-size of the alloy investigated. In most cases of stress-corrosion, the crack is arrested after propagating a short distance and cycles of corrosion and mechanical failure occur before failure is complete.[12]

The preceding mechanism indicates that the resistance of the alloy to stress-corrosion depends on; (*a*) the difference in electrode potential between the grain-boundary regions and the grains; and (*b*) the difference in strength between the precipitate-free zones of solid solution (at the periphery) and the solid within the grains. If the latter were the dominant factor then the variation of susceptibility to stress-corrosion failure with ageing time would be similar to the hardness *v.* ageing time curve (the hardness of the precipitate-free zones would remain essentially constant during ageing). In fact, this is not so. It has been found that in aluminium-zinc-magnesium alloys the susceptibility increases with ageing time to a maximum value, after which the resistance improves,[6,13] and that during the stage of increasing resistance the material is still hardening.[6] It appears, therefore, that the susceptibility is determined largely by the corrosion factor. This is not unexpected since the importance of corrosion is demonstrated by the protective influence of a direct current, and by the fact that in sheet form, commercial aluminium-zinc-magnesium alloys are protected by cladding with an aluminium–1% zinc alloy.[14] However, the importance of the mechanical aspect must not be underestimated. It may explain, for example, why certain aluminium alloys which are susceptible to intercrystalline corrosion are not liable to failure by stress corrosion.[15]

The differences in grain-structure between the high-purity alloy and commercial material may necessitate some modifications to this theory. However, the fact that the same conditions exist in the commercial alloys, i.e. a difference in electrode potential between grains and grain boundaries, and the presence of precipitate-free zones of solid solution, suggests that the same general mechanism will apply.

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Loewy German Order

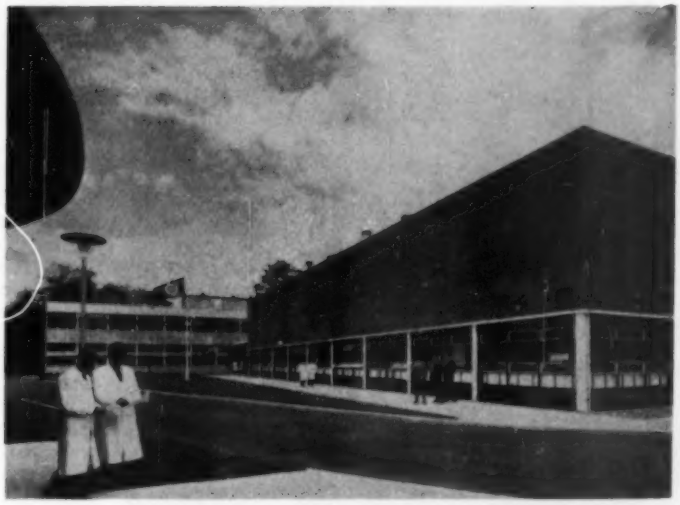
THE Loewy Engineering Co., Ltd., has received through Mannesmann Export G.m.b.H., an order for the supply of a mains frequency induction heating installation for steel billets. The equipment will be installed at Mannesmann A.G., Roehrenwerk, Remscheid, Germany, and the value of the order is over a quarter of a million pounds. The equipment to be supplied is for a nominal capacity of 21 tons/hr., with provision made to increase the output at a later stage to 28 tons/hr. It will have a power rating in excess of 10 MW., and it is the largest induction heating installation in the world ordered for a steel extrusion plant. The billet heating equipment is for use with a Loewy 3,100 ton hydraulic extrusion press plant for steel, of new design, which is at present under construction.

Beryllium Monitor Exports

EXPORT orders totalling £15,000 have been received from United States, France and Japan for the beryllium monitor manufactured and marketed for Winston Electronics, Ltd., Shepperton, Middlesex, and developed by the United Kingdom Atomic Energy Authority. The equipment detects and automatically records the quantity of beryllium dust in workshops where beryllium metal and its alloys are worked. The very minute quantities of beryllium, which is toxic, in the atmosphere, are spectographically measured at one-minute intervals.

Combustion Research

New Shell Laboratory at Egham



General view of the Combustion Laboratory at Egham.

THE Shell Combustion Laboratory which was recently transferred from Fulham to a larger, specially-built laboratory at Egham, Surrey, had its beginnings in a small laboratory set up at Lensbury Wharf, Fulham, in 1927, for the purpose of testing fuel oil burners. When this establishment moved to larger premises in Fulham in 1930, a small laboratory for testing kerosine burning appliances was also set up. Both laboratories expanded over the years, and in 1955 were amalgamated to form the Continuous Combustion Laboratory, being simultaneously integrated with the Central Laboratories. The new buildings, specially designed for what is now known as the Combustion Laboratory, supplement those at Egham accommodating the other facilities offered by the Central Laboratories, which comprise the following sections: analytical, automotive, bitumen testing, fuels testing, lubricants testing and materials inspection.

The move to Egham will enable the Combustion Laboratory to meet the increasing demands of development and technical service. Notable among its past contributions to oil-firing practice was the part it played in the development of the fully automatic preheating pressure-jet type of burner. It also gave valuable assistance to Sir Frank Whittle in the development of a combustion chamber for his first jet engine.

The principal objectives of the new laboratory are the continued promotion of the highest standards of performance and reliability in the use of liquefied petroleum gas, kerosine and other oil fuels; and to provide the support needed for the technical service which is available to customers and appliance manufacturers through Royal Dutch/Shell Group marketing companies all over the world. A wide range of applications is covered in the Combustion Laboratory, extending from small caravan gas cookers to the largest oil burners used in steel furnaces and industrial boilers.

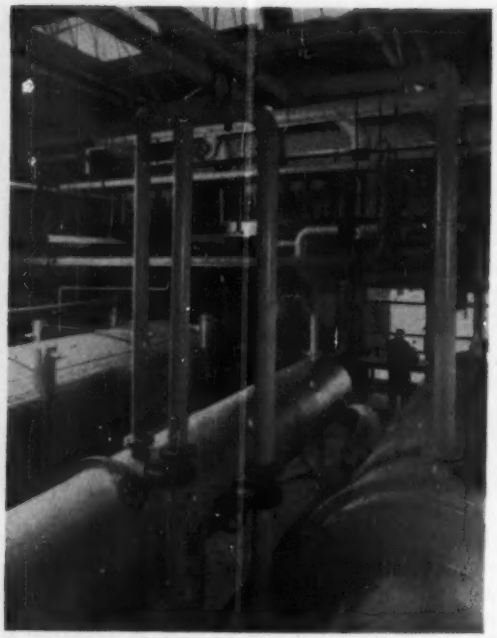
Laboratory work on the fuels referred to above, starts at the refineries, where the laboratories ensure that they meet various quality requirements by means of special physical and chemical tests for determining such properties as flash point, viscosity, calorific value, etc. The Egham Laboratory is part of the Shell marketing organisation and its work is concerned with the behaviour of fuels in the equipment and appliances in which they are intended to be used. This is a continuing activity because new appliances and plant are constantly appearing and respective fuel requirements must be determined; because established appliances are being modified and a solution must be found for any fuel problems thrown up; and because there is a steady probing for new or modified fuels capable of giving better service in existing appliances.

In a speech on the occasion of the recent Open Day, Mr. C. B. Davies, Head of Oil Products Development Division, Shell International Petroleum Co., Ltd., emphasised that the Egham Combustion Laboratory is just one of a number of laboratories in the Shell family where similar oil and gas firing studies are in hand, co-ordinated to extract the maximum in useful results from the overall effort. In the U.K., the Thornton Research Centre near Chester plays an important part in this effort, and laboratories in Holland, France and Germany are also involved. This international aspect of Shell combustion work facilitates efforts to encourage good national standards and codes of practice and puts the company in a good position to help equipment manufacturers and users on export matters. The Egham laboratory is concerned with the United Kingdom and with countries that do not have a combustion laboratory.

Layout, Services and Architecture

The layout of the laboratory is based on three main sections—service block, test block and administration block. The first of these accommodates stores, central heating boilers, plant rooms, and fully equipped machine and electricians' shops responsible for ancillary engineering services and maintenance for the whole of the Central Laboratories.

The test block deals with large scale work, carried out in three main rooms. Firstly, the large combustion



A general view of the large combustion chamber room.

chamber room, containing a furnace 4 ft. square and 15 ft. long, and two water-cooled cylindrical combustion chambers, one with an internal diameter of 2 ft. and the other with one of 3 ft. 9 in. Secondly, the boiler room, containing boilers of sizes ranging from small domestic units to a large central heating boiler with a capacity of 2 million B.t.u. an hour. Thirdly, the general test room. This contains a wax spray rig for determining the particle size distribution produced by fuel oil atomisers, rigs for determining the functional characteristics of nozzles, and a small water-cooled combustion system for the investigation of combustion and associated problems. Facilities also exist for the temporary erection of special furnaces. Also included in the test block are a number of small rooms in which temperature and humidity can be controlled to facilitate the investigation of special aspects of combustion.

The administration block contains the normal office facilities and a drawing office, which are on the upper floor. There are also five small laboratories for specialised work on small equipment such as kerosine appliances, liquefied petroleum gas appliances, small pumps and atomisers, and automatic controls. Three rooms are specially equipped for training and demonstration purposes ; a large one for fuel oil and kerosine applications, and two small ones for liquefied petroleum gas, domestic and industrial applications.

The services provided within any building of a technical nature are of major importance to its successful operation. There are in this laboratory, in addition to normal electrical heating and ventilation runs, twenty-two different services piped throughout the test area. These include air at high, medium and low pressure ; town gas, propane and butane ; nine different oil fuels from kerosine to 3,000 seconds fuel oil ; mains water and cooling water ; and three-phase and single-phase electricity with variable voltage supplies. Each of these has to be immediately accessible so that existing equipment may be modified or further equipment installed as required.

The operation of any boiler or burner under test necessarily produces heat, and one of the greatest design problems was the removal of heat from the large test boilers and furnaces, and its subsequent dissipation in a manner not likely to cause a nuisance. The method adopted makes use of a closed water system to which any water-cooled test equipment can be connected. Cooling water is pumped through these and thence through an air-cooled heat exchanger, located outside the building, with a capacity of 5 million B.t.u. an hour. Louvres and electrically driven fans, automatically controlled so that the water temperature is maintained between certain limits, are mounted above the heat exchanger. There are nine control stages, starting with the louvres closed and the fans idle. The louvres are opened to provide natural draught cooling and the fans are then progressively turned on to augment this. Protection has been provided against damage to the heat exchanger by freezing.

Domestic services are operated as far as possible on Shell products. Central heating is provided from oil-fired hot water boilers, and hot water in lavatories is supplied by multipoint instantaneous water heaters fired by propane, a liquefiable petroleum gas.

The architecture of the new laboratory was conceived to meet a number of functional problems. The different sections demanded different room heights, and since each test unit has its own separate flue, the arrangement of flue exits demanded careful thought. At one stage it was hoped that they could be concealed, or at least grouped. Concealment, however, was not possible, as there must be no risk of impeding the free discharge of flue gases. Visibility of the flue terminals being inevitable, they have been designed to present a number of varying architectural shapes against the sky.

A striking feature of the building is the blank brick wall of the test block, with the glazing under it. This wall was designed without applied decoration, the interest being provided by its proportions and the materials used. The link between the two main blocks is the low level entrance hall, the continuation of the paving area forming a wide apron to the building. This also gives both a physical and a visual link between the new Combustion Laboratory and the older buildings.

Considerable thought has been given to the use of colour. Internally, cool colours have generally been used, enlivened by the more positive colours used in the coding of the various exposed services. It was felt that no attempt should be made to conceal these services, and by careful control over design and installation the identifying colours of the pipes have been welded into an acceptable pattern. Externally, the quiet colours of the aluminium sections and the vitreous enamelled infilling panels of the administrative block complement the colour and texture of the brickwork, the whole being enlivened by the use of external sunblinds in bright orange.

The Work of the Laboratory

In addition to the investigational experimental work carried out, the Combustion Laboratory also plays an important role in the training of Shell technical staff in the practical application of the fuels. As an example of this aspect of the Laboratory's work, Shell have pioneered

the introduction and development of liquefied petroleum gas (LPG) in many overseas areas, and staff trained in all aspects of its use are needed to train and advise local agents in its correct application and handling. Courses are arranged at the laboratory to train the necessary staff.

Space will not permit a comprehensive detailed description of the equipment and activities of the Combustion Laboratory, but a brief reference to some of the items on which work has been, and is being, undertaken will give you an indication of the type of problem being studied. Not unnaturally work on various types of burner features prominently in the Laboratory's programme as will be seen in the following account.

Burners

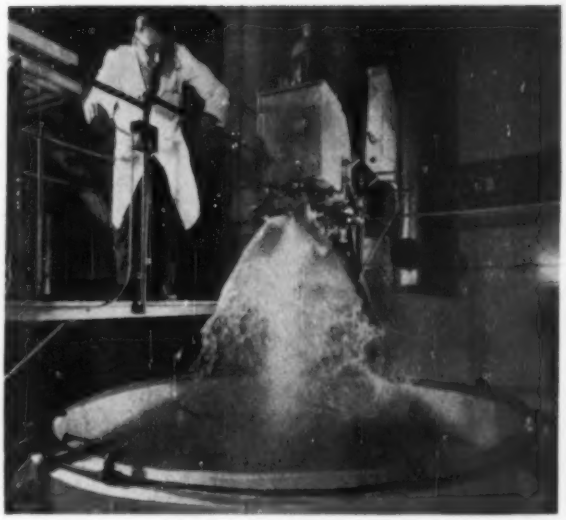
An LPG burner has been developed which has a turn-down ratio well in excess of 100 to 1 and a high stability achieved in the following manner. Premixed propane and air are directed from the burner head annulus in the form of a divergent cone. This flow induces a toroidal vortex within the cone which brings part of the hot combustion products back down the cone axis to join with the emerging propane/air mixture, thus ensuing that the flame root remains established at this point. Very high propane/air exit velocities, and hence high volume throughputs for a given burner size, can therefore be used without blow-off occurring.

Also developed for use with propane are the tunnel (or jet) burners designed to produce a very hot, very high velocity gas stream to achieve rapid heating by forced convection. The heating is achieved by direct impingement of the hot gas stream onto the material undergoing treatment. As little or no refractory is required, tunnel burners can be used for heating very soon after lighting.

The Spill-Y-burner is a small capacity, variable output, medium pressure air atomising sprayer of the internal mixing type. It is a development of the Shell Y-type burner, from which it differs only in the method of oil metering. Tests on this burner have shown that it will turn down from a maximum of 3·2 gal./hr. to a minimum of 0·1 gal./hr. on gas oil (supplied at 100 lb./sq. in.). It has also operated satisfactorily on preheated (220 sec. Redwood I at 100° F.) fuel oil down to 0·15 gal./hr.

A general investigation into various design factors affecting air entrainment and flame characteristics with oil burners for open hearth steelmaking furnaces and glass melting tanks is about to be made. Facilities are available at the Combustion Laboratory for testing burners and examining combustion conditions at firing rates up to 50 gal./hr. under operating conditions similar to those pertaining in practice. The steam atomising burner when set up for testing, fires into a furnace which has been specially constructed to produce high temperature operating conditions. A second burner has been installed to raise the furnace temperature initially. Connected to the same induced draught or natural draught chimney system, are two water-cooled combustion chambers for use where the burner to be tested is intended for low temperature applications such as boilers.

The assessment of the overall performance of a fully automatic preheating heavy fuel oil burner involves the measurement of a large number of variables. At the recent Open Day a demonstration showed an Urquhart medium pressure air atomising burner fitted to a Beeston



The wax spray rig used for determining the particle size distribution produced by fuel oil atomisers

Brigadier type 9BRN boiler and the techniques used by the Combustion Laboratory for making such an assessment. The following are determined: (1) the relationship between the Shell smoke number and the air fuel ratio as assessed by percentage CO_2 in the flue gases; (2) the effect on combustion of (*a*) atomising air pressure, and (*b*) fuel temperature (viscosity); (3) variation in fuel temperature at the atomiser; (4) variation in Shell smoke number when starting in a hot and cold combustion chamber; (5) operation of the nozzle shut-off valve; and (6) the performance of the fuel oil pump, air compressor and all other auxiliaries.

Testing Equipment

All types of nozzles may be tested on one or more of four permanent test rigs. The light oil spray rig is used for testing nozzles on distillate oils and has a maximum capacity of 25 gal./hr. at 400 lb./sq. in. Nozzles may be calibrated at any desired pressure, the spray observed, and the spray angle measured.

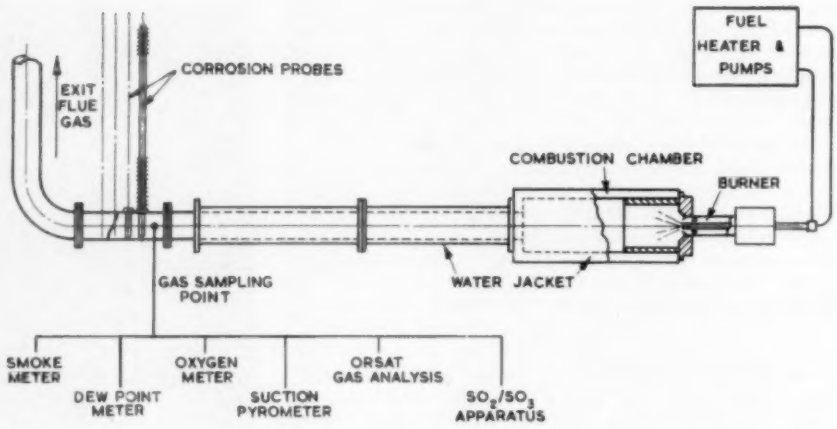
The Patternator is for measuring the spray distribution of a nozzle and has a maximum capacity of 20 gal./hr. at 200 lb./sq. in. The nozzle is mounted to spray vertically downwards into a cylindrical drum which is divided into twelve equal sectors. The sectors are drained to separate measuring flasks and, thus, the polar distribution of the spray may be determined.

Used for testing nozzles on preheated heavy oil, the heavy oil spray rig is at present under reconstruction to increase its capacity to 800 gal./hr. at 1,000 lb./sq. in. Nozzles may be calibrated at any desired pressure and fuel viscosity, the spray observed, and the spray angle measured.

The wax spray rig is for measuring the size of the particles in the spray from a nozzle and has a maximum capacity of 50 gal./hr. at 400 lb./sq. in. A special blend of wax is used to simulate the fuel and the liquefied wax is supplied to the nozzle at the required pressure and viscosity (temperature). The spray is enveloped by a water curtain and the particles freeze in flight. The

solid particles and water are collected, and a sample taken for size analysis by sieving.

The pressure jet nozzle is sensitive to fuel viscosity and therefore to fuel temperature. If the viscosity of the fuel becomes too high (temperature too low) the nozzle will not function efficiently as an atomiser. To check that a burner or a fuel will be satisfactory at low temperatures the laboratory is equipped with a cold room in which can be placed the burner and its fuel supply, so that the burner is able to fire into a boiler placed outside the cold room.



Diagrammatic arrangement of stack solids rig.

An interesting item of experimental plant is the stack solids rig, so named because it was originally constructed for work on the solid particles carried in the flue gases produced from an oil burner. The rig shown diagrammatically in the sketch is, essentially, a burner firing into a water-cooled combustion chamber from which water-cooled flues progressively reduce the flue gas temperature so that, by varying the flue length, experiments can be carried out at any gas temperature desired. Recently, the rig has been more widely used for flue gas corrosion assessment by many techniques and for many materials, and this work is still being carried out to-day. It might seem that the corrosion resistance of various materials would be well known or could be determined by simpler methods than by immersing specimens in flue gas. In practice this is not so. Not only do the specimens have to be immersed in flue gas, but to obtain reliable data they have to be held there at constant temperature over a comparatively long period. For this reason the Laboratory developed the liquid-cooled corrosion probe which has been fully described elsewhere.

The measurement of the temperature of a hot gas is not a simple matter if the gas is at a temperature different from its surroundings. The method normally employed to achieve a reasonably accurate result is to use a suction pyrometer. In this instrument a thermocouple is surrounded by one or more shields and the gas whose temperature is being measured is drawn over the couple and between the shields at high speed. There is a need for a small portable instrument of this type which can be used by field engineers and servicemen. The Laboratory is developing such an instrument (for temperatures up to 1,000° C.) which can be used as an accessory to the Shell smoke meter.

Testing oxy-propane steel cutting equipment.

Miscellaneous

No account of the work on the industrial uses of fuels derived from petroleum would be complete without a reference to the use of oxy-propane burners for steel cutting, flame cleaning and washing, hardening and stress relieving, non-ferrous metal welding and billet heating. The Combustion Laboratory is concerned with the development of oxy-propane equipment, and even more with the training in its uses of Shell overseas technical staff.

On the domestic side, the Laboratory undertakes work on kerosine fuels and appliances, including cookers and lamps, and as part of these studies is preparing to carry out a survey to evaluate in measurable terms, noise generated by domestic oil-burning installations.

Conclusion

These few examples of the Laboratory's activities, show the way in which it fulfils its function of conducting investigational experimental work in connection with the use of petroleum products used for heating purposes, with the object of raising the efficiency of heat utilisation. Special attention is paid to industrial problems raised by customers, and there is close contact with the technical staffs of many different industries and organisations.

View of the "new" premises from Sycamore Avenue. The semi-circular-topped window at the near end of the two-storey section provides an entrance to the modern reception hall which was formerly the engine house.

From Textiles to Diecastings

Conversion of a Redundant Cotton Mill

LANCASHIRE has never been entirely dependent on the cotton industry. Large areas are—in contrast to popular belief—agricultural, but even in the so-called "cotton towns" such industries as engineering, papermaking, etc., have long had a firm foothold. Nevertheless, long before World War II, many towns realised the danger in having too many of their eggs in one basket, and set themselves out to attract new industries. In consequence, the recent closing down of a number of cotton mills and the concentration of production in fewer units, under the Government's reorganisation scheme for the industry, has been carried out with less hardship than might otherwise have been the case. These closures have made redundant not only workers, but industrial premises also, and several of the latter have been acquired by expanding concerns in other fields for conversion to their own use. The transformation, by Thomas Ashworth & Co., Ltd., of a Burnley cotton mill into a modern diecasting plant provides an interesting example of diversification of industry in a formerly depressed area—engineering replacing textiles.

Lest it be imagined that Thomas Ashworth & Co., Ltd., is one of the firms attracted to Lancashire in recent years, let it be said at the outset that the company was established in 1828 to make iron castings, and produced during the last century many hundred miles of the decorated railings so prominent a feature of the North of England until World War II, when they were ruthlessly cut down to provide scrap for the steel industry. Between the two wars, aluminium sand casting was introduced, and later aluminium gravity diecasting when this process was still in its infancy. During the last war, many millions of diecastings were produced for such things as tank periscopes, bomb sights and predictor equipment. Until recently the various production and administration departments were housed in two establishments situated in different parts of Burnley, and the expanding business was crying out for more space, all at one site. The redundant cotton mill in Sycamore Avenue—with a total site area of 130,000 sq. ft. and a floor area (including offices) of 90,000 sq. ft.—provided it.

Transformation of the Premises

The new premises were built in two stages, one of them fifty years ago, and the other as recently as ten years ago, and conversion from cotton weaving to diecasting was a major operation. Apart from the production departments, two features of special interest in the converted premises are the main office and the reception hall. The former, on the first floor, was originally the preparation warp sizing section, and a special ceiling has just been installed to provide: (*a*) sound absorption (necessary for open planning); (*b*) fire resistance; (*c*) heat insulation (to keep the offices warm in winter and cool in summer); and (*d*) a return for the air in the special heating and ventilating system. The ceiling is constructed of expanded metal supported by T-section aluminium. Over the expanded metal is a layer of tissue paper, and on this a layer of Vermiculite. The ventilating system, arranged by the company's combustion division, is essentially a ducted supply of filtered and warmed air to the offices and reception hall. With the special ceiling no return duct is necessary; the air returns above the ceiling. The air, heated by steam from the main boiler, is controlled by a modulating

Noise-absorbing ceiling of novel construction in the combined general and drawing office.

The Centrallograph installed in the works manager's office provides a record of the production performance of up to twenty diecasting machines, together with reasons for stoppages.

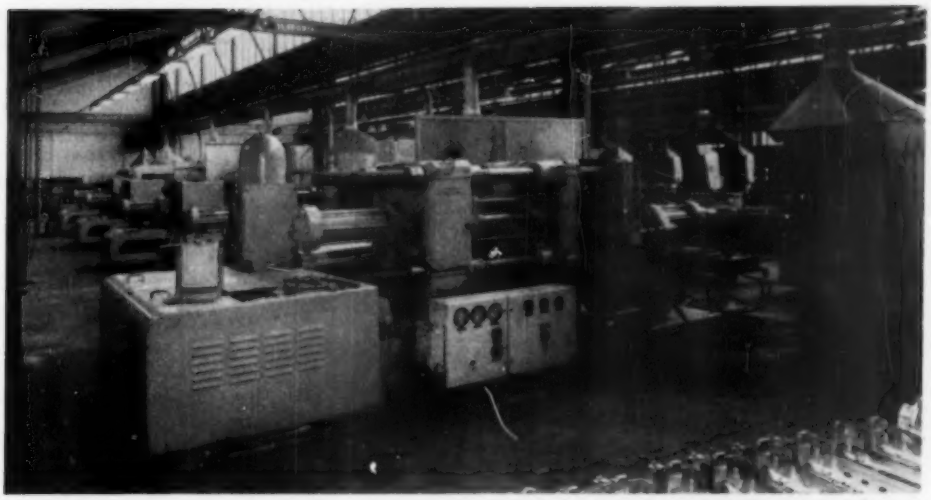
thermostat operating a motorised valve : the proportion of fresh air to returned air can also be controlled.

Perhaps the most striking transformation has taken place in the old steam engine house, part of which now forms the reception hall. Here the layout and décor are in the modern idiom, with a sound absorbing ceiling dotted with " stars " in the form of small lamps sunk into the acoustic tiling at irregular intervals. Sound absorbing panels are also hung between the interviewing alcoves, so that several groups can carry-on their respective conversations simultaneously without interference from their neighbours. To give the hall better proportions the ceiling has been lowered relative to that of the engine house. Adjacent to the reception area, two offices have been built over the area where coal for the original Lancashire boiler was tipped. The latter has been replaced by a John Thompson treble pass economy boiler. This is rated at 3,000 lb. of steam per hour at 60 lb./sq. in. pressure, and is oil-fired by a Hamworthy B.5 forced draught rotary cup burner using 3,500 seconds oil. The boiler is fully automatically controlled, and was installed by Ashworth's combustion division. In the remainder of the old engine house are to be found the main and standby compressors, the former, driven by an 80 h.p. motor, delivering 300 cu. ft. of air per minute at 150 lb./sq. in.

Production Departments

Realising the importance of pleasant working conditions the company has paid special attention to those twin trouble makers, fumes and noise, receiving valuable help from the Department of Scientific and Industrial Research in finding solutions to the noise problems arising in various parts of the works. Most of the metal

Schultz 350-ton locking force machine engaged in the production of zinc-base diecastings. This unit is equipped with electronic control of all production factors.



General view of the line of machines producing aluminium diecastings.

used in the foundry is melted by gas, but oil-fired furnaces are being introduced : over 2¼ million cu. ft. of gas are used each month. All the furnaces are hooded and fumes are extracted by five fans, each taking 6,000 cu. ft. of air per minute. This fume extraction system presented a noise problem not only within the factory, but also in the neighbourhood of the works where there are many dwelling houses. Noise minimisation, if not abatement, was achieved by fitting to each fan a silencer to the company's own design.

Casting

The foundry is situated in the newest part of the building, and at the side nearest the offices there is a line of zinc pressure diecasting machines. There are three Kipp Caster No. 215 machines with a maximum metal injection pressure of 0·5 tons./sq. in. and capable of making castings up to 6 oz. in weight ; and two E.M.B. No. 12 machines with a die locking force of 35 tons, a maximum casting weight of 4 lb., and a maximum metal injection pressure of 1 ton./sq. in. The largest machine is a Schultz, with a die locking force of 350 tons, a maximum casting weight of 10 lb., and a maximum metal injection pressure of 2 tons/sq. in. This machine is fully electrically controlled so that all the valuable factors in diecasting production can be set to give the best results for each die. All the machines have thermostatic control of metal temperature, and all casting production is covered by the British Standards Kite Mark Scheme.

Parallel with the zinc line is a row of machines for pressure diecasting aluminium and its alloys. The die locking force on the 2 E.M.B. No. 12 (converted) machines is 35 tons, the maximum casting weight 1 lb., and the maximum metal injection pressure 2 tons/sq. in. Of the four Reed-Prentice machines, three have a die locking force of 250 tons and the other, one of 150 tons. All have a maximum casting weight of 3½ lb. and a maximum metal injection pressure of 7 tons/sq. in. The maximum casting weight in the Buhler 400 machine with its 400 tons die locking force—is 8 lb., and the maximum metal injection pressure 15 tons/sq. in. The Buhler and Reed-Prentice machines are fully controlled for the diecasting cycle, with electronic timers, and have " shot control " on the injection system.

All the pressure diecasting machines are connected to the Centrallograph in the works manager's office. This equipment records each shot of each machine and indicates when a machine has stopped production. The reason for the stoppage is indicated on the chart by a code number which can be dialled by the operator at a point near the machine. It is expected that the Centrallograph will ensure maximum utilisation of the diecasting machines.

The foundry also has a section devoted to the gravity diecasting of aluminium alloys and of aluminium bronze. The largest gravity diecasting produce is 36 in. in diameter and weighs 50 lb., while the smallest weighs less than an ounce.

All the usual foundry alloys are used, including the high strength ones requiring heat treatment.

Kipp Caster machine shown producing small zinc-base castings.

Pouring a gravity diecasting.

Finishing

The trimming of castings is effected by presses wherever possible, the equipment available including a 30 ton Bipel hydraulic press, a 20 ton Bliss crank press, a 12 ton H.M.E. crank press, a 7 ton air-operated press, and various small hand toggle presses for small castings. Gravity diecastings have their runners and risers cut off by band-saw and the trimming of these castings is mainly done by filing and burnishing. Dust extraction equipment is fitted to all burnishing and polishing machines, and sound absorbing booths have been built round the band-saws to cut down the penetrating noise.

Many castings are finished by roto-barrelling, and two barrels are working practically all the time. Other operations carried out include polishing, wire-brushing, drilling, tapping and simple machining. Where anodising or electroplating is called for, these operations are carried out in the nearby works of an associated company.

Inspection

The inspection department is approved by the Inspectorate of Armaments (War Office), the Ministry of Aviation, and the Inspectorate of Fighting Vehicles. All castings pass through the department and most are covered by a visual inspection, but flatness checking, pressure testing and gauging are carried out on some.

Toolmaking

The accuracy and quality of both gravity and pressure diecastings owes much to the tool room where the dies are made. Special alloy iron is used for the gravity dies, and forged alloy steel is always used for the pressure aluminium dies. The tool room is manned by twenty-six skilled craftsmen who have at their disposal five lathes, seven milling machines, an 18 in. shaper, a Taylor-Taylor-Hobson three-dimensional pantograph, two surface grinders, two pillar drills, a radial drill, and two tool and cutter grinders. The largest lathe swings 48 in. diameter and the smallest 7 in. diameter. Of the seven milling machines, three are universal, including a new Huron machine, and one of these is fitted with hydraulic copying equipment.

Products

The company believes in spreading its output over as wide a range of industries as possible. This was evident from a glance at the products displayed in the reception hall when the new factory was inaugurated recently. Castings are made for over two hundred manufacturers as parts for such diverse products as surgical bone drills, aircraft radar, scientific instruments, stiletto heel tips, smoking pipe stems in which an internal thread is cast, and washing machines.

The factory employs 228, including 55 women, and some 14,000 castings per day are despatched, ranging in weight from 50 lb. to fractions of an ounce. Many of the castings are incorporated in equipment destined for export markets, and it is estimated that some 260,000 Ashworth castings found their way to the United States last year. In the production of these castings some 16 tons of metal are consumed each week.

Besides diecastings Thomas Ashworth & Co., also manufacture and market Taco textile equipment such as weavers' and warpers' beams and cloth rollers in light alloy (incorporating die cast flanges), which weigh 30–50% less than old-style equipment for this purpose. Perhaps better known in the field of metals is the Speedy moisture tester which finds widespread application in the foundry for sand testing. Its use is not confined to the foundry, however, and some 2,000 a year are sold in sixty different countries, U.S.A. alone taking about 400. Seventy per cent. of the production is exported and it is believed that around 20,000 are now in use. A further division caters for heating installations —both domestic and industrial—an outcome of one of the firm's earliest ironfoundry activities.

Diecasting Advisory Service

The company wisely undertakes advisory work in the diecasting field. Many potential customers have little knowledge or experience of the possibilities and limitations in the process, and are inclined to ask for the straightforward replacement by a diecasting of a part previously made in some other way. In such cases, it may be necessary to re-design the part when the change is made from the point of view of ease of production, cost and satisfactory service behaviour. Numerous examples of such replacements are included in a booklet, "Problems in Metal," which sets out the relationship between the firm and its customers from the moment an enquiry is made. The case histories mentioned concern the replacement by aluminium or zinc-base diecastings of steel pressings, iron castings, aluminium sand castings, and hot brass pressings, and in each case the advantages accompanying the change are listed. There have been instances where the company has advised against diecasting when some other method was better. Recent examples include a knob where a part turned from bar was more suitable; a connector where an extrusion gave the best results; a drawer handle where again an extrusion was better; and an overheating release where spot-welded pressings were cheaper. This realisation that using diecasting where it is unsuitable can only bring discredit upon the process, and the courage to tell a potential customer so, must have played no small part in engendering the confidence its two hundred customers have in the diecasting division of Thomas Ashworth & Co., Ltd.

New Ore Sintering Plant at Workington

Increasing Use of Norwegian Concentrates

General view of the sinter plant and the raw materials stockyard.

THE new £2½ million single strand continuous sinter plant at the Workington Iron & Steel Co. branch of The United Steel Cos., Ltd., was officially opened by Crown Prince Harald of Norway on 6th December, 1960. Designed to produce each week 12,500 tons of self-fluxing sinter, it is now in full operation. As is the usual practice with important United Steel developments of this type, the project was given a code name—Focus—standing for "Foreign Ore Concentrates Usage"

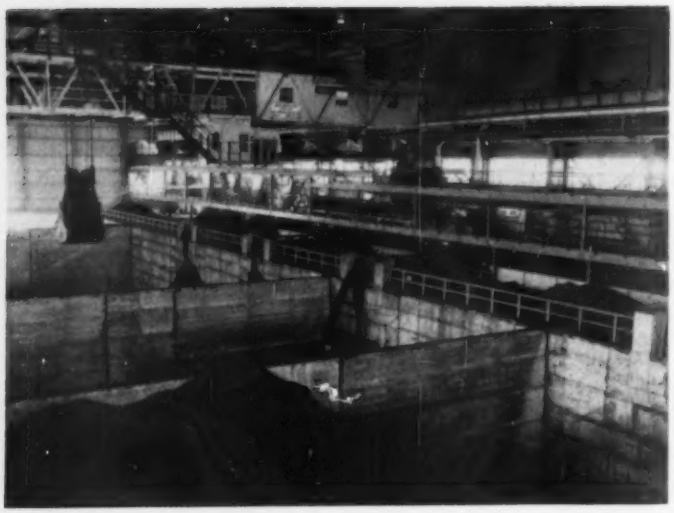
The Workington Iron & Steel Co. owes its existence to the deposits of rich hematite ore found in West Cumberland, but although the local ore is still mined, the deposits are no longer large enough for present-day needs. Considerable tonnages are therefore imported through the company's Workington Dock, which is 1,000 ft. long and can accommodate vessels of up to 10,000 tons deadweight. Through the dock also pass some of the finished products of the works, which specialises in permanent way material—rails, sleepers, fishplates, soleplates, etc.—for the railways of the world: nearly one-third of British Railways' requirements are met by the company. In addition, semi-finished and bar material is supplied to the engineering and motor industries and is rapidly becoming an important part of the company's trade. Steel production in the last full year totalled 320,000 tons, and the figure for 1960 is expected to be considerably higher.

One of the first to adopt the revolutionary new steelmaking process invented by Bessemer just over a hundred years ago, the Workington Iron & Steel Co. is the only firm in the United Kingdom producing steel by the acid Bessemer process today. By its nature, the process is unable to remove any phosphorus from the iron during its conversion to steel, and it is therefore essential to start with raw materials low in phosphorus and other impurities. The Cumberland hematites meet these requirements and also that of a high iron content, but, as stated above, these are no longer sufficient to meet the demand. It is intended that about 60–70% (400,000 tons a year) of the ore charged into the blast furnaces will be imported from Norway, and the remainder provided from other overseas sources and the company's own hematite mines in Cumberland, which are currently producing about 120,000 tons a year.

The Norwegian ore will be supplied by the Sydvaranger Co., whose opencast workings are situated at Bjornevatn, a few miles south of Kirkenes in the far north of Norway. After crushing on site, it takes a five-mile train journey to the port, where there are extensive installations for crushing, magnetic separation and drying of the ore. Finally, in the form of concentrates containing 65% iron, the ore is loaded by conveyors into ocean-going vessels for shipment to Workington and other steelworks in the Western world.

Benefits of Sintering

Sintering is now widely practised at many British steelworks. It consists of agglomerating fine ores, concentrates, and limestone under heat provided by coke. The resultant product can thus be made of a suitable size and strength to form the burden in the blast furnace, where the sintered ore is transformed to pig iron. At one time sintering was merely regarded as



Interior of the stockyard building, showing storage bays, overhead crane and conveyor belt system.

a means of dealing with material too small for charging into the blast furnace, and with dust trapped in the dust catcher, etc. More recently it has been realised that the process provides a means of blending and mixing the constituents of the burden so that a uniform and consistent product is obtained, with consequent improvement in the uniformity and quality of the iron produced in the blast furnace. The crushing operations carried out on the Sydvaranger ore before beneficiation by magnetic separation result, of course, in a product—concentrates—which must be sintered before charging into the blast furnace.

Sintering was originally adopted at Workington in 1943. The plant was subsequently expanded to produce about 6,000 tons of sinter per week, and has clearly shown the advantages to blast furnace performance of the use of sinter. To modify it in order to produce the additional quantities of sinter which are now needed would not have been an economic proposition, and the decision was therefore taken to build the new plant with a capacity of 12,500 tons of sinter per week.

From the dock at Workington, imported ore is conveyed by railway wagons to the material storage building, which has a capacity for 44,000 tons of ore fines. This is additional to the previously existing stockyard capacity of 100,000 tons, and in this way it is possible to stock sufficient material to cover ten weeks' operation, thus safeguarding any interruptions to ore shipments.

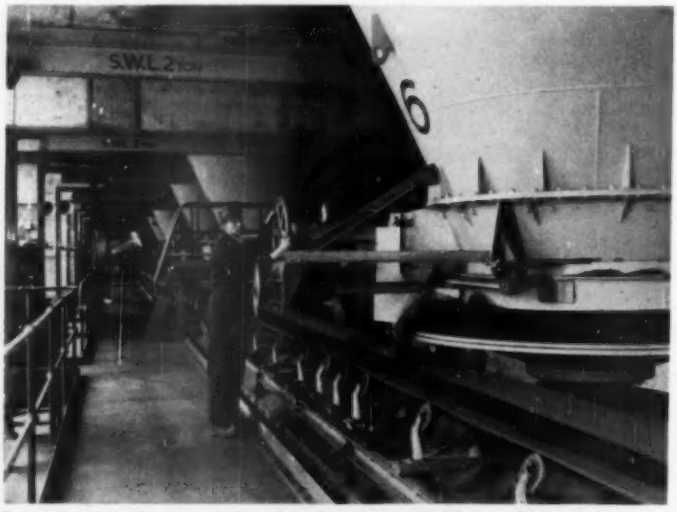
The New Plant

The storage building is divided into five separate bays with the following capacities: Sydvaranger concentrates, 16,500 tons; hard ore fines, 11,500 tons; soft ore fines, 9,000 tons; home ore fines, 7,000 tons; and coke breeze, 350 tons. From the stock bays the ore fines are transferred by overhead grab crane to any of thirteen raw material bins and are held there ready for mixing in the desired proportions for sinter. Coke breeze is pulverised at the existing coke oven plant, and limestone, which provides the self-fluxing element, is crushed in a plant adjacent to the main building.

Sinter mixture materials are fed on to a gathering belt by 9 ft. diameter rotary feeder tables fitted with speed adjustment; in addition, the coke feeders have independent speed control. After primary mixing in a twin paddle rotary drum mixer of 200 tons/hr. capacity, the mix is conveyed onwards to a surge hopper from which it is fed under control to a pelletising drum. In this drum, the final mixing and adjustment of water content is made. Pelletising increases the permeability of the sinter bed on the strand and permits a faster sintering rate. To avoid degradation of the fragile pellets, a vibrating feeder is installed to transfer the mix from the pelletising drum to the sinter strand.

The Head Wrightson/McKee single strand continuous sintering machine is 6 ft. wide and 180 ft. long, equipped with twenty-eight wind boxes and having an effective grate area of 1,008 sq. ft. Strand speed is variable between 45 and 170 in./min., the mix being ignited by an automatically regulated mixture of blast furnace and coke oven gases with combustion air. The ignition furnace or hood is 6 ft. 2 in. long by 7 ft. 8 in. wide and operates normally on a blast furnace/coke oven gas ratio of 7 : 1. The design nevertheless caters for operation on either 100% blast furnace gas or 100% coke oven gas. The air blower has a designed capacity of 2,500 cu. ft./min. at 12 in. w.g.

Gas from the wind boxes is collected in a straight dust collector wind main of increasing cross-sectional area,



Raw feed gathering belt, showing storage bins: the operator is adjusting the ore feed.

the last 90 ft. long section of which acts as a dust settling chamber.

Discharged sinter passes through a breaker with 6 in. knife spacings to a Schenk vibrating screen. By means of a variable speed feeder, the oversize sinter is fed to a Lurgi-Frodingham circular cooler with a designed capacity of 100 tons/hr., the temperature of the sinter being reduced from 850° C. to 100° C. during its passage through the cooler. Pallets in the cooler discharge the sinter into a hopper for transfer via a variable speed feeder and a conveyor to a further screen at which the sinter may be separated into two size ranges before delivery by transfer car to the furnace bunkers.

The hot undersize sinter is carried by a tray conveyor from the sinter screen to a quenching station. Here, a Schenk screen mounted over twin 50 ton capacity bunkers divides the returns into two size fractions, $+\frac{3}{8}$ in. for bedding material and $-\frac{3}{8}$ in. for use as return sinter. After cooling, the bedding fraction passes to a 55 ton capacity surge hopper with a rotary feeder table from which it is fed back to the sintering strand. The return sinter fraction ($-\frac{3}{8}$ in.) is transferred to the return fines storage bins in the material storage building.

Sintering machine viewed from the discharge end, showing chain of pallets filled with sinter. The ignition hood can be seen in the background.

Four Buell dust extraction systems are employed to collect the dust arising at various points in the plant and to discharge it finally into the primary mixing mill. These systems serve the conveyor lines in the material storage building; the discharge end of the sinter machine and sinter cooler area; the quenching station area; and the high line screening station area.

From the initial commissioning stage, output from the new sinter plant is being brought up gradually to its rated capacity. Early indications are that the beneficial effects anticipated on blast furnace operations will be more than fully realised, as even in the present intermediate stage, a reduction in blast furnace coke consumption has been made possible following the use of this sinter.

Titanium Hooks for Nickel Plating Baths

Over and above its well-established use for steam heating coils, I.C.I. titanium is now making another important contribution to efficient and economic nickel plating—the provision of "non-consumable" hooks for supporting nickel anodes. The cost of anode hooks represents quite a sizable factor in the economics of nickel plating. Their weight (between 4 and 8 oz.) is added in with that of the anode, so that they are paid for at virgin metal prices. Once used, they cannot be relied on for further satisfactory service, and the most the user can hope for is to recover the scrap value of the metal. The difference between buying and selling price corresponds to a loss of at least 1s. a hook.

This, however, is not the only disadvantage of using nickel hooks. The plating solution which dissolves the anode will naturally have a similar effect on a hook of the same metal. For this reason, some form of protective sheathing of the hook is necessary. In addition, it is usual to work with the hook, and often the top inch or so of the anode too, above the surface of the solution. This not only presents technical disadvantages; it also means that the anode is incompletely used.

Hooks made of titanium are so impervious to attack by nickel plating solutions that they can be used as permanent fixtures—they are screwed into the anode in the normal way and transferred from each finished anode to the next one. Titanium hooks installed early in 1958 are still in service. Apart from wear on the thread, which does not affect performance, they are in perfect condition and are expected to last at least as long again.

Titanium is completely resistant to all commonly-used dull and bright nickel plating solutions. Consequently, the hook can be taken right down into the solution, and the whole surface of the anode is in contact with the plating solution. Laboratory tests over many months by a manufacturer of nickel anodes show that there is no preferential dissolution of the nickel near the thread. This confirms the experience of platers, who find that full immersed anodes wear more evenly and can be used more completely. In practice, therefore, the reduction in anode cost in considerably more than 1s. per operation.

On 21st November the British Aluminium Co., Ltd., opened its Bedford district sales office at Swan House, 3 High Street, Bedford (telephone: Bedford 5428; telegraphic address: Britalumin Bedford). This new district sales office covers the counties of Northamptonshire, Huntingdonshire, Bedfordshire, Cambridgeshire, Norfolk and Suffolk. The district manager is Mr. C. L. Reynolds.

New and Revised Standards

Aircraft Material: Corrosion-Resisting Chromium Steel (Free Machining) (B.S. S.124: 1960). Price 2s. 6d.

A new standard in the aircraft series, "S.124, Corrosion-Resisting Chromium Steel (Free Machining)", replaces Ministry of Aviation specification D.T.D. 525. During the transfer of this specification, the opportunity has been taken to introduce certain technical changes: in particular the standard now specifically requires that the steel shall not contain lead or selenium.

Methods for the Analysis of Iron and Steel. Part 41: Lead in Carbon Steel and Low Alloy Steel. (B.S. 1121: 1960. Part 41). Price 3s.

The forty-first part of B.S.I.'s comprehensive series of standards dealing with methods of analysis of iron and steel has just been published. It deals with the gravimetric determination of lead in steel, and supersedes Part 1C of B.S.1121. The method applies to carbon steels and low alloy steels containing chromium, copper, molybdenum and nickel, with lead contents up to 0·05%. Tin up to 0·25% and tungsten up to 2·0% do not interfere. This standard—and others in the series—will prove of particular value as a referee method.

Galvanised Mild Steel Wire for Armouring Cables (B.S. 1442: 1960). Price 4s.

Now that it has been revised, this British Standard applies only to galvanised mild steel wire used primarily for the armouring of land cables for electrical purposes. Requirements for galvanised mild steel wire for the armouring of submarine cables have been transferred to B.S. 1441, to be published soon.

In the 1948 edition of B.S. 1442, the resistivity of the wire was stated as an ohm/mile constant, but it was not a specified requirement. However, with the increasing use of non-metallic sheathed cables in which the wire armour serves as the sole earth continuity conductor for certain purposes and types of cables, the resistance of the armour becomes important. Therefore, in the revised edition, there is a clause stating that for certain purposes and by agreement between purchaser and manufacturer, the D.C. resistance of the galvanised wire shall be measured. Maximum resistance figures are given for each of the sizes of wire and for convenience are expressed in ohms/1,000 yd. of wire at 20° C. (68° F.).

The standard applies to fully galvanised mild steel round wire in sizes ranging from 0·160 in. to 0·018 in. Tests and tolerances are specified and details are provided relating to the preferred sizes, the selection and testing of test samples, re-tests, galvanising, resistivity, and packing and identification.

Electroplated Coatings of Cadmium and Zinc on Iron and Steel. (B.S. 1706: 1960). Price 5s.

This revised publication specifies the purity, appearance, thickness and adhesion of coatings; the corrosion resistance of passivated coatings; and the appearance, covering and adhesion of a chromate film: classification is in all cases by thickness. Full test procedures for establishing the quality of the coatings are given in a series of appendices. They deal with: local and average thickness; adhesion; humidity (in relation to passivated coatings); and the presence and adherence of chromate film. A sampling method is specified—and there are recommendations for sampling small articles which would normally be barrel plated. Other recommendations concern the heat treatment of plated articles of steel with a nominal tensile strength of 65 tons/sq. in. and over.

Methods for the Analysis of Aluminium and Aluminium Alloys. Part 11: Silicon (Perchloric Acid Method). (B.S. 1728: 1960: Part 11) Price 3s.

This new publication is the eleventh in a series which—when all the constituent parts have been published—will form a complete British Standard: "Methods for the Analysis of Aluminium and Aluminium Alloys." All the methods in the series have been found to give reliable and reproducible results. B.S.1728 Part 11 specifies the reagents required; recommends methods of sampling; and gives the analytical procedure for the determination of silicon in alloys having a silicon content from 0·1% to 24% or over.

Ingot Tin. (B.S. 3252: 1960). (Price 4s.)

This new British Standard specifies requirements for three of the most widely used grades of tin: high purity tin; refined tin; and common tin. The chemical composition of each grade of tin is provided. (Standard methods of analyses for these three grades are in course of preparation). Among the requirements in the general clauses of the 9-page specification are those relating to: selection of test samples; retests; certificate of compliance; inspection and marking.

Sampling of Imported Iron Ores Part 1: Hammer and Shovel Method (B.S. 3278: 1960: Part 1). Price 3s.

This new British Standard is the first of a series dealing with the sampling of ores and is designed to meet the growing need for a standardised form of preparation of iron ore samples at United Kingdom ports. The differing conditions at ports, as well as the varied nature of imported ores, limit the detail which can usefully be incorporated in a standard, but the basic principles which apply in all cases are covered.

Part 1 has been prepared recognising that ships of larger tonnage than hitherto will come increasingly into use, necessitating more rapid methods of sampling by mechanical means. This part applies to sampling of imported iron ores from ships' holds at the port of arrival immediately after arrival. Recommendations are made for the method of selection of sub-samples and the number of increments, the method of sampling, the gross sample and reduction to the certificated sample, and the final samples. A plan of sampling and sampling reduction is included, as well as an appendix giving an example of the general procedure recommended.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. Postage will be charged extra to non-subscribers.

Physical Properties and Constitution of Liquid Slags

By B. T. Bradbury,* B.Met., Ph.D., and D. J. Williams,† B.Sc., Ph.D.

A knowledge of the structure of liquid slags is of vital importance in leading to a better understanding of their functions in process metallurgy. Interest in their structure has grown with the development of the thermodynamic approach to slag/metal reactions, and in many instances a structural model is an important aid to the correct interpretation of these reactions. In the present article the authors review the physical properties of simple slag systems, paying particular attention to the more recent findings in this field of metallurgical research.

(*Continued from page 240 of the December, 1960, issue*)

II. BORATE SYSTEMS

Analogous experimental techniques to those described above for the work on the silicates, have been used for studying borate melts. Electrical conductivity data has been reported by Bockris for the system PbO-B_2O_3; densities and viscosities have been measured by Shartsis[23c] and co-workers, whilst Shartsis and Capps[24] and Shartsis and Shermer[25] have studied the surface tensions of alkali and alkaline earth borates.

A serious difficulty in connection with the work on binary borates is the restricted field of the binary systems due to the regions of immiscibility as indicated by the phase diagrams. Erroneous interpretation of data can result if the phase diagrams are ignored. Thus, Bockris'[22] interpretation of the fall in the energy of activation for electrical conductance (E_K), on the addition of 8 mole-% PbO to B_2O_3 must be viewed with some caution, since the phase diagram is not definitely known for this region, and there is some evidence for the existence of a two-liquid region.[26] This fact apart, however, Bockris'[22] data for the region above 40 mole-% PbO (Fig. 7), shows a decrease in E_K for the conduction process, which is indicative of a structure breakdown taking place over this composition range.

Structural interpretations from surface-tension measurements on the borates are not very satisfactory because of the pronounced immiscibility effects exhibited by these systems. The PbO-B_2O_3 system is no exception in this respect. In a study of the surface-tensions of melts in the systems PbO-B_2O_3 and PbO-SiO_2, Shartsis, Spinner and Smock[23b] deduced that the marked immiscibility in the PbO-B_2O_3 system, made it impossible for any detailed structural interpretations to be made. A large two-liquid area extends from about 9·0 to 43·0% PbO, and over this composition range the surface tension and its temperature coefficient remain approximately constant. This condition probably indicates that the composition of the surface layer is quite different from that of the interior of the liquid and, since the surface-tension differs but little from that of pure B_2O_3, it seems safe to assume that this layer consists essentially of pure B_2O_3. From about 40 to 80% PbO, the surface-tension rises rapidly to a flat maximum near 84% PbO,

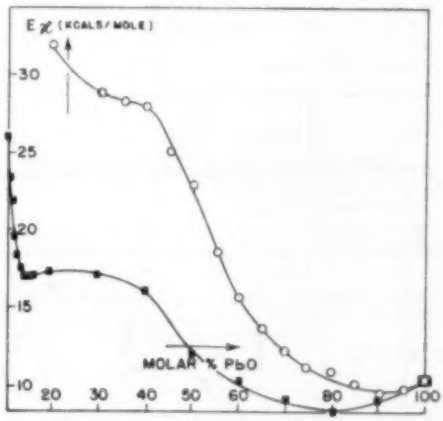


Fig. 7.—Energy of activation of electrical conductivity (E_K) versus composition for the PbO-B_2O_3 (squares) and PbO-SiO_2 (circles) systems.[22]

this increase probably being due to a breakdown of the three dimensional BO_3^{3-} network which is also indicated by the fall in E_K values as determined by Bockris.

Bockris[22] suggests that at 75% metal oxide, discrete BO_3^{3-} ions exist and, as the B_2O_3 concentration increases, chains appear. At 50% B_2O_3, these chains decompose to give ring formations. It is interesting to note that pure B_2O_3 exhibits a positive temperature coefficient of surface tension.[27-29] This observation is compatible with King's[15c] theory, that positive $d\gamma/dT$ values in network structures can be explained by a mechanism other than surface adsorption—a reason which has often been put forward for the existence of anomalous $d\gamma/dT$ values.

Viscosity, Density and Surface Tension Measurements

Shartsis[23] and co-workers have studied the binary borates of sodium, lithium, calcium, barium and strontium, and obtained evidence for the occurrence of structure breakdowns in these systems. The data obtained is shown diagrammatically in Fig. 8. On addition of the first 10% metal oxide to B_2O_3 there is a radical reduction in the viscosity, coupled with an increase in surface tension, density and thermal

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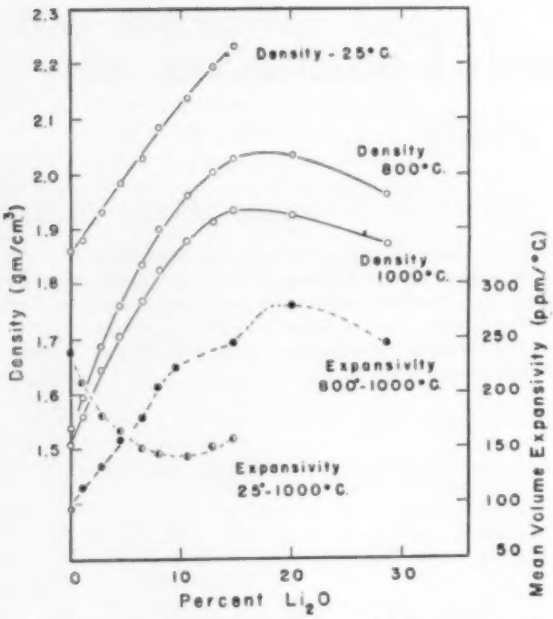
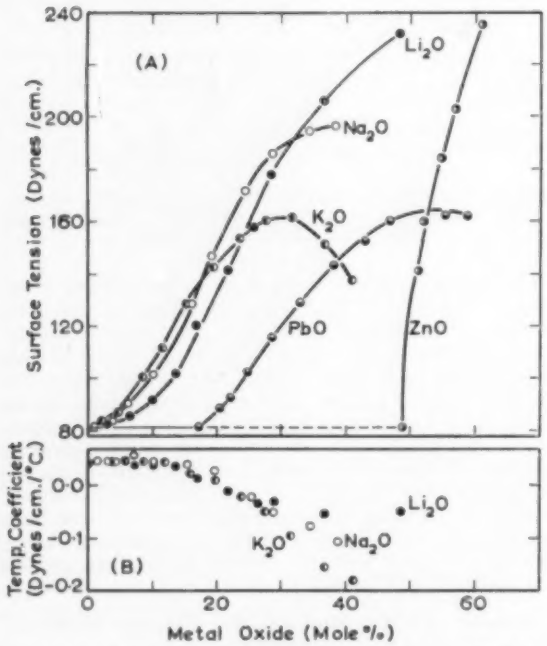
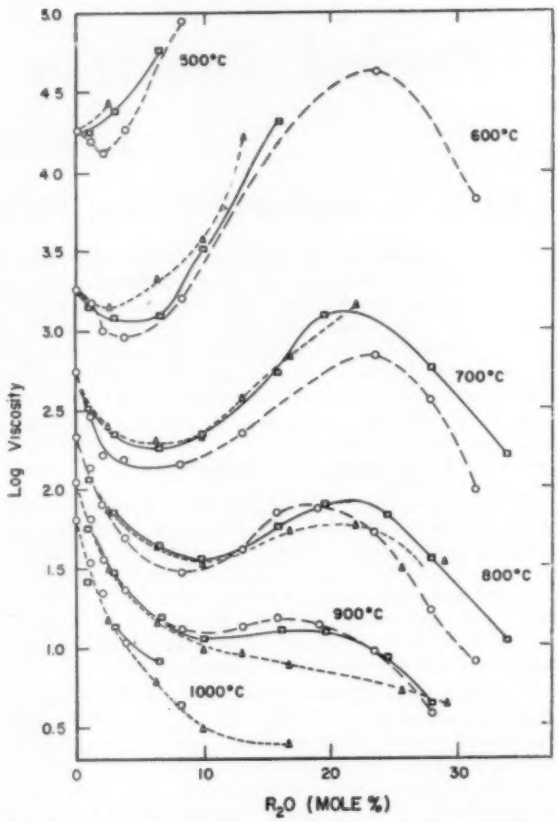


(a) Density and mean expansivity of lithium borates.

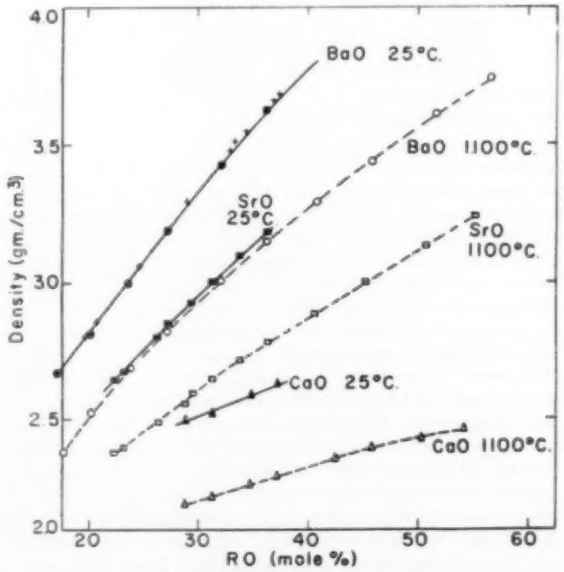


(c) (A) Surface tension of some binary borates at 900° C. (B) Temperature coefficient of surface tension of alkali borates at 900° C. Filled circles—Li_2O liquids; hollow circles—Na_2O liquids; circles with left half filled—K_2O liquids; circles with bottom half filled—PbO liquids; and circles with right half filled—ZnO liquids.[21]

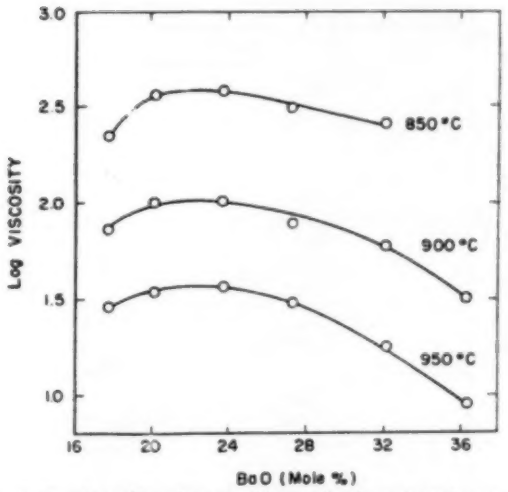
Fig. 8.—Density, viscosity and surface tension of simple alkali oxide borates (a, b, c) and simple alkaline earth borates (d, e and f).



(b) Viscosity of alkali borates: triangles—lithium borates; squares—sodium borates; circles—potassium borates.[23a]



(d) Density of alkaline earth borates at 25° and 1,100° C. Crosses represent densities at 25° C. of barium borate glasses (which received different annealing treatments) available from another investigation.[23]

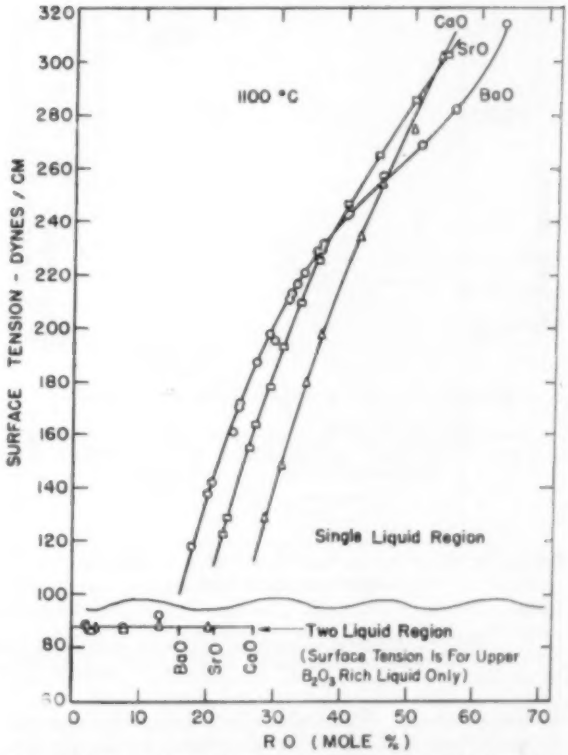


(e) Log. viscosity of some binary barium borates as a function of BaO concentration.[25]

expansivity. The changes in surface tension, viscosity and thermal expansivity, as we have already seen, can be taken to be indicative of a structure breakdown The density increase given here must be due to the close. packing of the borate ions as metal oxide additions are made.

Further addition of metal oxide beyond 10% results in a maximum in the log viscosity-composition curve at approximately 25 mole-% metal oxide, together with maxima in the surface tension and density curves near 30 mole-% metal oxide. These effects suggest at first sight a structure build-up giving a viscosity increase and decreases in surface tension and density. However, on consulting the phase diagrams for these systems, it is found that the situation is further confused by the presence of large immiscibility gaps, and by the fact that some of the diagrams have not been determined over the composition ranges of interest. Because of these confusing factors, it is felt that structural interpretations of physical property measurements on binary borates are liable to be erroneous unless they are made in careful consultation with the phase diagrams available. Similar effects to those mentioned above have been noted by Kruh and Stern[30] for melts in the system B_2O_3-NaF (see Fig. 9). Fluoride additions result in a marked increase in density accompanied by a decrease in viscosity, and this seems compatible with the collapse of a large, open network into smaller structural units which are at the same time more mobile and more efficiently packed. Upon addition of more solute, the density continues to increase although the viscosity increases. Kruh and Stern[30] have attributed this effect to the transition from three- to four-fold co-ordination and the coupling of tetrahedral units. In the case of Na_2O-B_2O_3 melts, they found that at sufficiently high concentrations, the viscosity passes through a maximum, and they have explained this on the basis that there are then enough anions present to reduce the need for sharing of tetrahedron corners. Devitrification effects prohibited the extension of measurements into this concentration range for the B_2O_3-NaF melts.

Surface tension measurements on B_2O_3-NaF melts have



(f) Surface tensions of some binary alkaline earth borates at 1,100° C: circles—BaO liquids; squares—SrO liquids; triangles—CaO liquids.[25]

recently been made,[26] and quite marked increases in these values have been noted on addition of NaF. This is in keeping with the now generally accepted rule that additions of network modifiers to lattice structures result in a structural breakdown, which results in an increased bond density near the surface and increases in the surface tension values.

III. PHOSPHATE SYSTEMS

There seems to be little published data on the molten phosphates, and the most recent work reported in the literature has been concerned with aqueous solutions of the polymeric phosphates. This work is recorded in great detail in a text book recently published by Van Wazer.[31]

It is sufficient to say here that standard techniques used in the analysis of high polymer solutions have indicated that in aqueous solutions of sodium phosphate glasses, long chain phosphates exist at the meta-composition and that these decrease in length as the proportion of metal oxide (soda in this case) increases. Viscosities of the aqueous solutions, *p*H titration techniques, and chromatography methods have all been employed to indicate this effect. Recently, Westman[32] has used the chromatographic technique to study solutions of potassium, sodium and lithium phosphate glasses, and found that a whole distribution of phosphate groups was present, comprising anything up to nine phosphorus

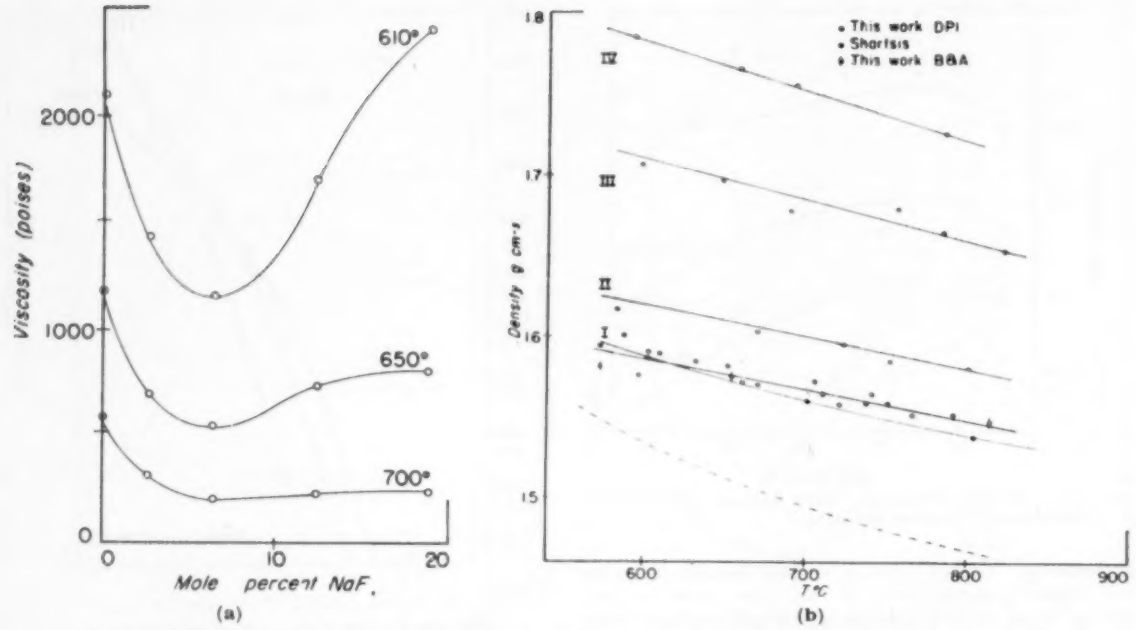


Fig. 9.—Change in viscosity (a) and density (b) with the addition of NaF to molten B_2O_3. Amounts of NaF in solution in B_2O_3 in curves I. to IV.: nil, 2·69, 7·65 and 12·4 mole %, respectively.[30]

atoms per chain. The distribution of these groups was dependent upon the metal oxide content of the glasses.

It might be expected that analogous reductions in the molecular weight of phosphate anions present in melts, would take place as the metal oxide content increased. However, the above chromatographic results do not really confirm the presence of exactly the same phosphate chains in the solution as are believed to be present in the melt. Available X-ray data due to Brady[33] indicate that polymeric chains exist in sodium metaphosphate glass, but that these are considerably distorted in the glass structure.

Viscosity Measurements

Viscosity measurements have so far been limited to sodium phosphate melts. Van Wazer[34] has measured the viscosities of melts in the composition range $Na_2O/P_2O_5 = 1{\cdot}00 \longrightarrow 2{\cdot}00$, using a rotational viscometer method. Additions of Na_2O resulted in a marked reduction in the energies of activation for viscous flow values, and this was interpreted as being due to a reduction in the length of the phosphate chain in the melt.

Surface Tension Measurements

Until recently, the only data available for the phosphates was the work reported by Callis, Van Wazer and Metcalf,[34] who measured the surface tensions of sodium phosphate melts over the composition range $Na_2O/P_2O_5 = 1{\cdot}0 \longrightarrow 2{\cdot}0$, using a modified maximum-pull-on-cylinder method. By combining the results obtained with the available density values (see next section), and using a derivative of the Eötvös equation, an apparent molecular weight for the molten sodium phosphates was estimated. The effective molecular weights in the molten state, as estimated in this way, were relatively low compared with the high degree of polymerisation found in solutions of the quenched glasses with Na_2O/P_2O_5 mole ratios near unity. However, it should be noted that the extension of the Eötvös expression to ionised melts represents a considerable extrapolation, and because of this the validity of the comparison will be somewhat reduced.

Recently, a detailed study has been made,[17] of the surface tensions of melts in the systems Na_2O-P_2O_5, K_2O-P_2O_5, CaO-P_2O_5 and Li_2O-P_2O_5 using a maximum-pull-on-cylinder method. The effects of composition, temperature and cation size on the surface tension values were investigated. The relationships obtained were, in fact, very similar to those reported by King[15a] for the silicates which have already been described. Thus, the results obtained indicated a relationship between surface tension and its temperature coefficient and the extent of electrical interaction between the cation and the phosphate lattice, as measured by the ion-oxygen attraction parameter Ze^2/R (see Fig. 10). The development of a theory for these observed relationships, and for the similar relationships reported for the binary silicates by King[15a] enabled some comparison of the liquid structures to be made. Application of this theory to the relationships illustrated in Fig. 10, has indicated that the charge on the oxygen ion in the silicate lattice is greater than the charge on the oxygen ion in the phosphate lattice at equivalent compositions. This finding would account for the low surface tension values of the phosphates relative to those of the silicates (Table I). The greater charge in the silicate case will mean a greater attractional force between the cation and the oxygen ion of the lattice and, if it is possible to envisage the magnitude of the surface tension forces as being determined in part at least by the attractional forces existing between (1) those phosphate or silicate groups which occupy a greater part of the surface (due to absorption effects), and (2) the metal cations positioned just below the

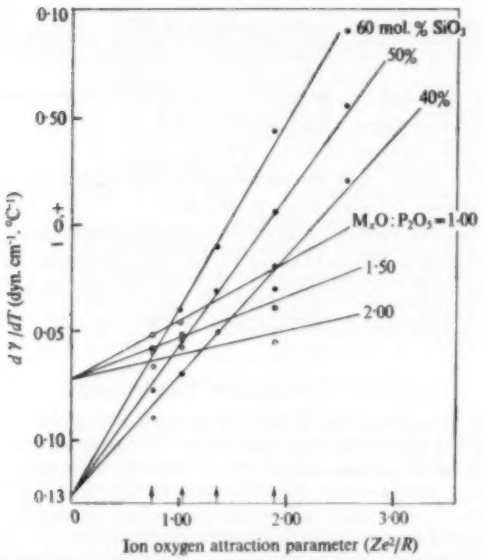


Fig. 10.—Temperature coefficient of surface tension versus ion-oxygen attraction parameter relationship for binary phosphates.[17]

surface layer and which draw the groups inwards, then the surface of the liquid silicate will be contracted to a greater extent, and surface tension values would be expected to be greater than those for the phosphates.

Surface-tension/composition relationships were all found to be linear in form which, as in the case of the silicates, is compatible with a progressive variation in the structure of the phosphate melt as the proportion of metal oxide varies.

Density Measurements

Van Wazer *et al*[34] have measured the densities of sodium phosphate melts over the composition range $Na_2O/P_2O_5 = 1{\cdot}00 \longrightarrow 2{\cdot}00$. Detailed structural interpretations of the results were not attempted. As was described previously, using the density results and the surface tension values which were determined in the same investigation, Van Wazer *et al*[34] estimated an apparent molecular weight for the molten sodium phosphates. Other density work has recently been carried out on sodium phosphate melts close to the meta-composition,[35,36] which were considered to be suitable test systems for investigating a structural breakdown process. Sodium fluoride additions were made as a means of effecting a structure breakdown, and the resulting structural changes were studied in some detail by density measurements, and by aqueous solution studies and infra-red absorption measurements.

The aqueous solution work indicated a marked reduction in the phosphate chain length on addition of sodium fluoride, and the infra-red absorption measurements made on samples of the quenched glasses gave a moderately detailed picture of the anionic units present in the melt. Marked increases in the density values were observed upon the addition of sodium fluoride to sodium metaphosphate, and these increases were interpreted as being due to a closer packing of the smaller phosphate anions resulting from the structure breakdown process.

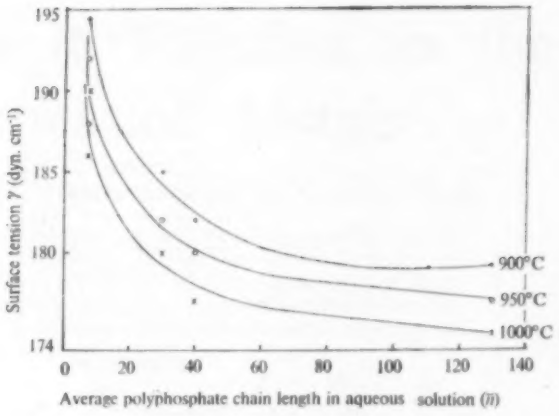


Fig. 11.—The effect of polyphosphate chain length ($\bar{n}$) on the surface tension values in the $Na_2O : P_2O_5$ system. $Na_2O : P_2O_5 = 1{\cdot}00$ composition.[38]

In accordance with what now seems to be a general rule, the structure breakdown effected by sodium fluoride additions increased the surface tension values to quite an appreciable extent.[38] This effect was interpreted as being due to an increased bond density near the surface, resulting in an increase in attractional forces. In an endeavour to relate the surface tension increases to some parameter closely characteristic of the breakdown process known to occur, the observed surface tension values were related to average polyphosphate chain length values in aqueous solution, and the resulting plots for sodium metaphosphate at a series of temperatures are illustrated in Fig. 11.

Infra-Red Absorption Studies

It is only comparatively recently that the usefulness of infra-red absorption methods in determining glass structures has been realised. Many infra-red absorption investigations, other than for structural interpretation, have been made in the past. Structural investigations are not so numerous, although several investigations which are of some interest are to be found in the literature. Simon and McMahon[37] have used the reflection method in a study of the infra-red spectra of the binary silicates, and observed anomalous effects in the case of potassium silicate which they related to the small ion-oxygen attraction value for the K^+ ion.

Anderson, Bohon and Kimpton[38] have studied the spectra and atomic arrangement in fused B_2O_3 and sodium borate glasses using the absorption technique. Until very recently, only two investigations had been made on glassy phosphate systems. Corbridge and Lowe[39] studied the infra-red spectra of a series of inorganic phosphorus compounds and characteristic frequencies were suggested for P-O-P linkages in the glass structures. Secondly, Bues and Gehrke[40] have made a detailed study of the sodium and potassium phosphates. Infra-red spectra for the quenched glasses and Raman spectra for the fused glasses were reported. Close similarities were observed in the two series of spectra obtained, suggesting a close relationship between the solid and liquid structures. Again, the potassium

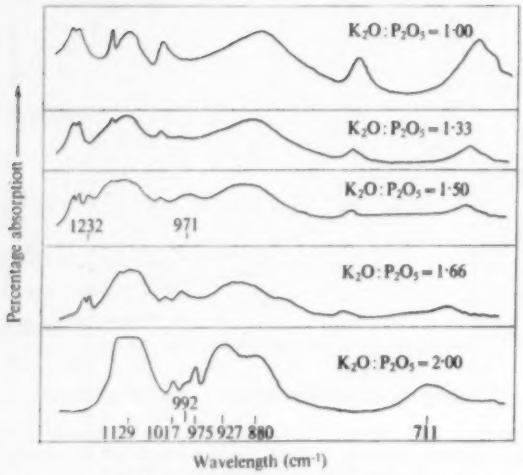


Fig. 12.—Infra-red absorption spectra for some $K_2O—P_2O_5$ glasses.[38]

phosphates were found to exhibit irregular spectra, and this anomalous behaviour has attributed to the difference in symmetry of the potassium polyphosphate chain.

Recently, infra-red absorption studies on a series of binary phosphate glasses and fluoride-phosphate glasses have been made.[35,28] These measurements constituted part of a full-scale investigation into the physical properties and constitution of long chain phosphate melts.[36] The spectra obtained were interpreted in terms of a gradual breakdown in the phosphate chain upon the progressive addition of metal oxide (Fig. 12). Further, by a comparison with the data reported by Corbridge and Lowe[39] and Bues and Gehrke,[40] it was possible to make suggestions as to the anionic entities in the melt. Observed changes in the spectra have given support to the theory that for any given composition and temperature, there is a definite equilibrium structure existing within the melt.

Summary

Electrical conductivity, viscosity, surface-tension and density measurements on silicates, borates and phosphates have been discussed, and the evidence from electrical conductivity and transport number measurements indicates the essentially ionic nature of silicate melts. There seems to be difficulty in deciding between the two rival theories of molten silicate structure due, respectively, to Bockris and to Richardson, since more experimental work is needed.

It has been particularly difficult to interpret the changes of physical properties with composition for binary borates, due to immiscibility regions in these binary systems. However, for the phosphate melts studied, some headway has been made in structural interpretations with the aid of infra-red and aqueous solution studies. Much more work is required on the phosphate systems before a detailed picture of the structure of these systems can be obtained.

Acknowledgment

Acknowledgment is made to those publications from which the diagrams have been reproduced, as indicated by the reference number at the end of the caption.

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New Works for Park Gate

THE Iron and Steel Board have approved proposals by the Tube Investments subsidiary, The Park Gate Iron & Steel Co., Ltd., for the development of a new integrated works on a site adjacent to the existing Park Gate Works near Rotherham. The proposals are designed to meet the increasing needs of the TI Group and those of Park Gate's traditional trade. They have also been planned to accommodate future modernisation of the existing steel works in perhaps ten or fifteen years' time.

The new works will use home ore and will initially include ore preparation plant, one blast furnace, a steel-making department producing steel by the Kaldo process and an electric furnace, and a blooming mill followed by a continuous billet mill. Finishing plant will include a 10 in. continuous rod and bar mill and a continuous narrow strip mill, which will be sited near to the existing 11 in. continuous bar mill installed in 1953.

The new works will cost between £55 million and £60 million, and will produce about 425,000 ingot tons a year. The iron and steel making at the existing works will continue, making a total ingot production by the company of 875,000 tons a year. All the ingots will be rolled in the new blooming and billet mills, and the semi-finished steel will be finished either on some of the existing mills or on the new finishing mills. There will be some increase in the billets available for outside sale.

The main engineering consultants will be The International Construction Co., Ltd., and Bylander, Waddell & Partners. Work will start in 1961, and the plant will be commissioned early in 1964 and be in full operation by 1965. It will be one of the most advanced and economical steel works in Europe. The cost will be financed by TI, partly from its own resources and partly by borrowing.

Press Order

THE LOEWY ENGINEERING CO., LTD., Bournemouth, has received an order for two modern high-speed forging presses of 800 and 600 tons capacity from Thos. Firth & John Brown, Ltd., Sheffield. These presses are of novel design, are oil-driven and are fitted with the latest type of auto-planishing and positional control gear. The Loewy Engineering Co., Ltd. is also at the present time building a 4,000 ton water-driven forging press for the same works. This press also is of new design and will be fitted with auto-planishing and positional control equipment.

Hot Hardness Values in Relation to the Physical Properties of Metals

By E. R. Petty*, B.Sc., Ph.D., and Hugh O'Neill†, M.Met., D.Sc.

Diamond pyramid tests at elevated temperatures on a modified machine have been made on various metals and alloys. There appears to be a direct relationship between the thermal coefficient of softening and the coefficient of thermal expansion. Elastic modulus for cubic type metals gives a linear relation with hardness. The log of various creep stress values when plotted against hot hardness values shows a direct relationship. The possibilities of hot hardness testing are discussed including its application to metals showing allotropic changes.

IN a previous paper[1] the hardness-temperature relationship was reviewed and published hardness values of metals were discussed in relation to melting points, thermal expansion and creep properties. The present paper reports some new hot-hardness results and develops the idea of further relationships. It will be appreciated that unless all the physical tests are carried out on the same casts of a given metal then differences in values due to (*a*) purity, (*b*) grain size, (*c*) residual stress, (*d*) cold work, and (*e*) variations of conditions of test might arise.

Hot Hardness Tester

In the present work the Vickers diamond pyramid indenter has been used with the load applied during 3–4 sec. and fully maintained for exactly 15 sec. Different metals and temperatures required different loads, ranging from 1 to 10 kg., but pyramid results are basically independent of load. The hot hardness tests were made in a modification of the apparatus described by Griffiths and O'Neill.[2] This utilises a Vickers machine with an enclosed specimen furnace on the stage. The specimen, which measured about 1 × 2 × 0·3 cm., was moved in a groove in a stainless steel anvil by a screw push rod. A 6 in. stainless steel hollow extension rod from the plunger of the testing machine passed through a bush lubricated with vacuum grease in the lid of the furnace. The details of the modified compound indenting rod are shown in Fig. 1. The internal ¼ in. diameter × 5 in. long feeler rod carrying the diamond was free to move vertically over a distance of 1 mm., and showed at a window in the extension when the indenter was just touching the specimen surface. This modification overcame a drawback inherent in the design of the earlier apparatus. A purified hydrogen atmosphere protected the specimen and indenter from oxidation.

Samples of various metals were obtained of at least 99·99% purity and, after annealing thoroughly, their hardness-temperature characteristics determined. The curves of log. hardness against temperature were in all cases linear with the usual inflexion near 0·5 of the absolute melting point (T_M °K.). This is in agreement with the Ito-Shishokin relation[3]:

$$H = Ae^{-BT} \qquad \ldots\ldots\ldots(1)$$

where H is the hardness at temperature T °K.,

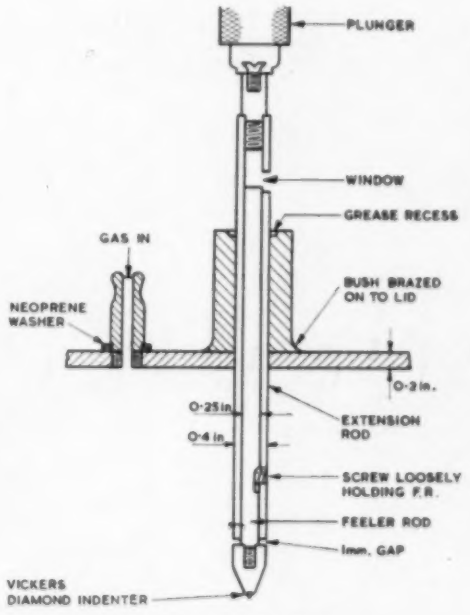

Fig. 1.—Details of indenter.

A is the extrapolated "intrinsic hardness" at 0°K., and

B is the coefficient of thermal softening.

The value of the slope B used in the following section was that for temperatures below 0·5 T_M.

Hardness and Thermal Expansion

In the previous paper[1] the suggestion was made that a direct relationship should exist between the rate of softening of a metal (B) with rise in temperature, and its coefficient of thermal expansion, α. Results for coefficient B have now been determined for pure face-centred-cubic metals and are plotted in Fig. 2 against coefficients of expansion obtained from Smithells. Values[4] for some body-centred-cubic (b.c.c.) metals are also included. The results validate the suggestion that for a given type of atomic packing there is a linear relation between the two coefficients, which for f.c.c. metals is expressed by :—

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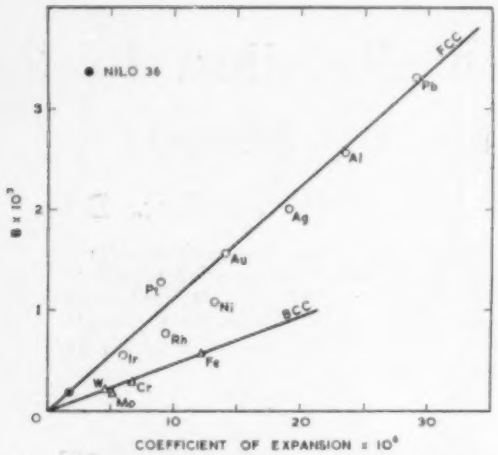

Fig. 2.—Relationship between softening coefficient (B) and thermal expansion coefficient.

$$B = 112a \qquad \ldots\ldots\ldots(2)$$

The results for b.c.c. metals suggest that the relation is again linear but with a smaller numerical constant. It must be noted that the results for B and a are for metals from different sources.

To investigate whether the graph actually passed through the origin, a sample of metal with near-zero expansion, i.e. Nilo 36 (36% nickel 64% iron) was tested. Over the range 0—200° C. this alloy has a reported expansion coefficient of $1{\cdot}98 \times 10^{-6}$, so hot hardness tests were made on cold-rolled specimens over the same range below recrystallisation temperature. The semi-logarithmic plot was not quite linear, but a fair estimate of B was $0{\cdot}22 \times 10^{-3}$. The result is included in Fig. 2 and falls near to the origin.

Coefficient B has been shown[3] to be related to the thermal energy of melting, both being dependent on the atomic bonding energy in a crystal. The coefficient of expansion must also be related to this energy of bonding,

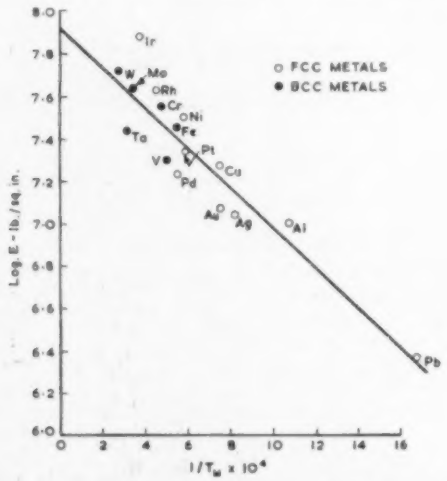

Fig. 4.—Relationship between modulus of elasticity (E) and melting point (T_M).

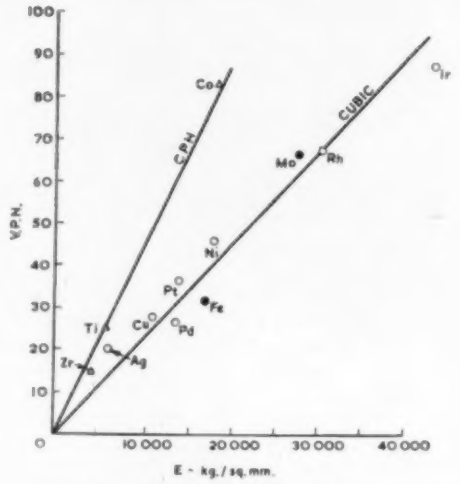

Fig. 3.—Relationship between hardness at 0·5 T_M and modulus of elasticity (E).

so that on theoretical grounds the relation between B and a is reasonably to be expected. A hypothetical metal which has no change in thermal energy of vibration with increasing temperature could also be expected to have zero B and a.

Hardness and Elastic Modulus

Indentation hardness often corresponds with reciprocal elastic compressibility, and it is a little surprising that a relationship between elastic modulus and temperature has not received much attention. Andrews[5] showed in 1925 that the modulus of elasticity E of metals decreased with temperature according to :

$$E = E_o\, e^{-bT} \qquad \ldots\ldots\ldots(3)$$

where E_o and b are constants which have two values each, one above $0{\cdot}5\ T_M$ and one below. E_o is the extrapolated modulus at 0° K. This is exactly analogous to the hardness-temperature relation (eq. 1), but a search of the literature reveals no indication of a connection between the two relationships.

It has been shown[6] that certain alloys with low coefficients of expansion have a zero temperature coefficient of elasticity. Again this is similar to the hardness behaviour described in the previous section.

A direct correspondence between elastic modulus E and Vickers hardness for tungsten carbide with varying percentages of cobalt may be deduced from the data of Lardner and McGregor.[7] Our plot of their results is linear from 5 to 25% cobalt.

Lozinski and Fedotov[4] have attempted to prove a linear relation between H and E for metals of commercial purity, but the results show considerable scatter. This is reduced at higher temperatures, and also when their results are replotted for the same homologous temperature of $0{\cdot}5\ T_M$ (Fig. 3.). In this latter plot two straight lines occur, one for close-packed-hexagonal (c.p.h.) structures and one for the cubic metals, but the materials used were not in the pure annealed condition so that scatter was unavoidable.

If elastic modulus is directly proportional to hardness, it should follow the same type of relationship as that found for room temperature hardness and melting point.

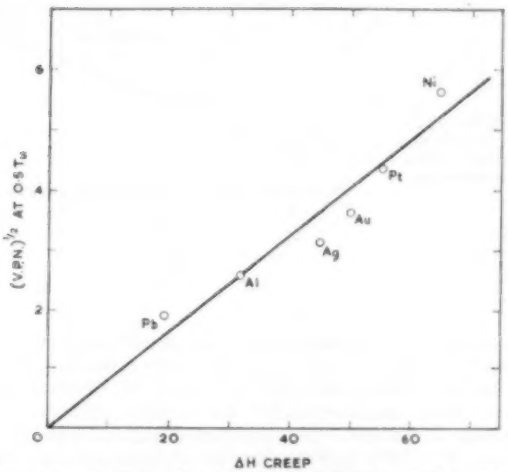

Fig. 5.—Relationship between hardness at 0·5 T_M and activation energy for creep (ΔH).

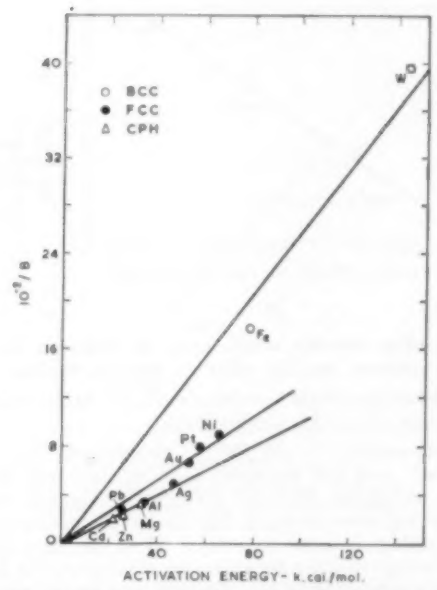

Fig. 6.—Relationship between softening coefficient (B) and activation energy for creep.

Using our newer results this equation has been corrected to :—

$$\log. H = 2{\cdot}3 - 3{\cdot}5\ T_R/T_M \quad \ldots\ldots\ldots(4)$$

Where T_R is room temperature ($\simeq 300°$ K.).

A similar curve for E is shown in Fig. 4 for cubic metals. A fairly good linear relation is seen to exist even though the data have been collected from different sources. The equation of this line is :—

$$\log. E = 8 - 1050/T_M \quad \ldots\ldots\ldots(5)$$

$(1050 = 3{\cdot}5\ T_R)$ so from (4) and (5) :—

$$\log. E = \log H + 8 - 2{\cdot}3$$

$$\text{or } E = H/2 \times 10^6 \text{ lb./sq. in.} \ldots\ldots\ldots (6)$$

Whilst the measured values for the thirteen metals shown in Table I show good agreement with eq. 6, more complex crystal structures give unsatisfactory results. At present, data for the constants involved are not in a suitable form for a closer correlation between H and E for all metals, nor for relations with more fundamental properties, e.g. atomic volume and binding energies.

Hardness and Extrusion

Shishokin[8] has obtained the following equation relating extrusion pressure P to give a fixed extrusion velocity, i.e. strain rate, to the temperature T :

$$P = Ae^{-\lambda T} \quad \ldots\ldots\ldots(7)$$

where λ is a coefficient different for each metal investigated. This expression is again seen to be identical in form with eq. 1 for hardness. It therefore seems reasonable to assume that hardness is in some way related to extrusion pressure, as both processes are governed to a large extent by the yield stress of the metal.

A relation between hardness and extrusion pressure may be seen from the data of Zeerleder[9] for aluminium alloys. O'Neill and Greenwood[10] have also identified extrusion pressure with the ball hardness of fully work hardened metals. This latter quantity they showed to be very approximately twice the Brinell number of the annealed material for a wide range of metals. A hot hardness test might be of use to establish the optimum temperature range for extrusion.[11]

Hardness and Creep

The flow of metals under a ball indenter was studied by Hargreaves[12] and a correspondence between hardness and creep has been shown previously.[1,13,14] So far the lack of a single standard testing procedure has obscured the precise relationships.

On a semi-theoretical basis a fair linear relationship was shown[1] between the square root of room temperature hardness and the activation energy for creep, ΔH_c, of many pure metals. The suggestion was made that better correlation should exist using the hardness value at $0{\cdot}5\ T_M$ and the activation energy, which applies to creep at and above $0{\cdot}5\ T_M$, where diffusion is the controlling factor.[1,15,16] Results obtained for some pure f.c.c. metals are plotted in Fig. 5, and seem to justify this proposal.

It was also proposed that the more quickly a metal softened with rising temperature the smaller would be the value of the activation energy for creep. The rate of softening, B (eq. 1) for some f.c.c. metals has been plotted in Fig. 6. Values for other metals[4] have been included, and the results seem to confirm that a linear

TABLE 1.—CALCULATED AND OBSERVED MODULUS OF SOME CUBIC METALS.

Metal	Hardness V.P.N. (kg./sq. mm.)	$E \times 10^{-6}$ (lb./sq. in.)	
		Calculated	Observed*
Al	16	8	9·9
Cr	70	35	36
Co	84 : 48	42 : 24	30
Cu	40	20	18
Au	27	13·5	11·5
Ir	170	85	75
Fe	55	27·5	28·5
Pb	4	2	2·2
Ni	63	31·5	30
Pa	37	18·5	17
Pt	40	20	22
Rh	100	50	41
Ag	25	12·5	11

* Smithells, C. J., Metals Reference Book, (London) 1955.

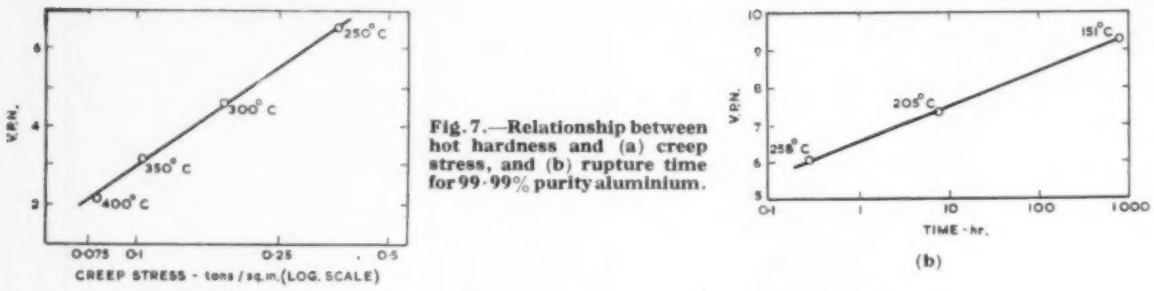

Fig. 7.—Relationship between hot hardness and (a) creep stress, and (b) rupture time for 99·99% purity aluminium.

relationship obtains which may be different for each crystal system, but the collected data are limited.

Hot hardness tests have been made on various materials for which creep data are available:

"Superpurity" (99·99%) aluminium has been studied[17] and hot hardness tests at 250°–400° C. were made on similar annealed material. These are plotted against log. creep stress in Fig. 7*a* and a semi-logarithmic relationship is seen to exist. They are also plotted against log. rupture time for pure aluminium[16] in Fig. 7*b*, and again a straight line obtains over the temperature range investigated.

Results for hot hardness of sintered 99·99+% nickel are plotted in Fig. 8 against time to give 10% extension under a constant load of 7 tons/sq. in.[18] Again a semi-logarithmic relationship exists.

The hot hardness[19] up to 1093° C. of vacuum cast molybdenum and annealed tungsten are plotted against 1,000 hour rupture stress[20] in Fig. 9. On the same graph the hardness values of strain hardened molybdenum and a rolled molybdenum–0·5% titanium alloy are plotted against 100 hour rupture strength.[19] In all cases a semi-logarithmic relationship exists.

Values of hot hardness[19] of the creep-resistant superalloy S816 have been plotted against log. 100 hour and 1,000 hour rupture stress in Fig. 10. Values of U.T.S. (which usually varies linearly with hardness) and 100 hour rupture strength[21] of a new high temperature alloy with a nickel-cobalt-chromium base are drawn semi-logarithmically in Fig. 11. All the graphs show a linear relation.

Average values for 1,000 hour creep rupture strength have been summarised[22,23] for ferritic and pearlitic nodular cast irons. The analyses of these are shown in Table II, which includes details of two standard S.G. irons—FN1 and PN1—on which we made hot hardness measurements. The analyses, hardness, and microstructures of the materials from both sources were very similar, and so the graph Fig. 12 was considered legitimate. There is again an excellent linear relationship over a range of temperature from 800 to 1,200° F.

Summarising these tests, it is seen that a linear relationship usually obtains between hot hardness at various temperatures and log. creep and stress rupture data—creep after all, is usually a logarithmic rate process.

TABLE II.—SPHEROIDAL GRAPHITE CAST IRONS

Reference	Hardness (V.P.N.)	Composition (%)				
		Total C	Si	Ni	Mg	Ce
F.N. (ferritic)	140–190	3·5±0·2	2·5±0·2	0–1·2	0·05–0·08	—
P.N. (pearlitic)	240–290	3·6	2·66	0·66	0·08	—
F.N.1 (ferritic)	140	3·6	2·01	0·66	0·7	0·015
P.N.1 (pearlitic)	230					

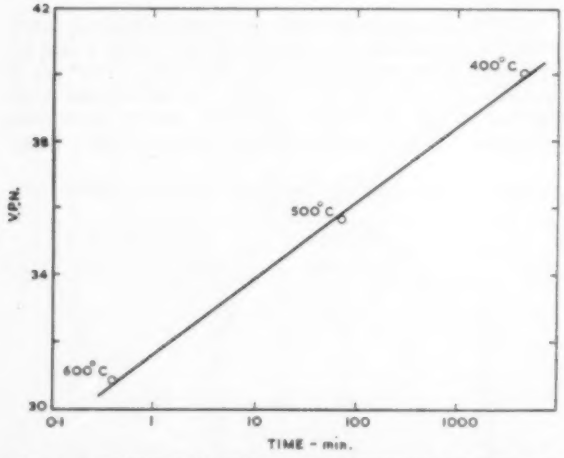

Fig. 8.—Relationship between hot hardness and time for 10% extension at 7 tons/sq.in. for 99·99% purity nickel.

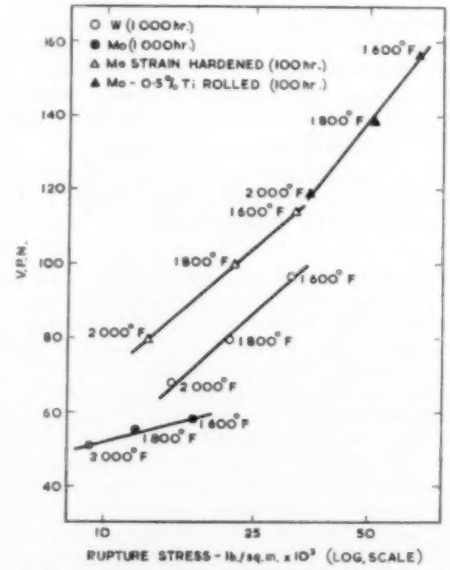

Fig. 9.—Relationship between hot hardness and rupture stress.

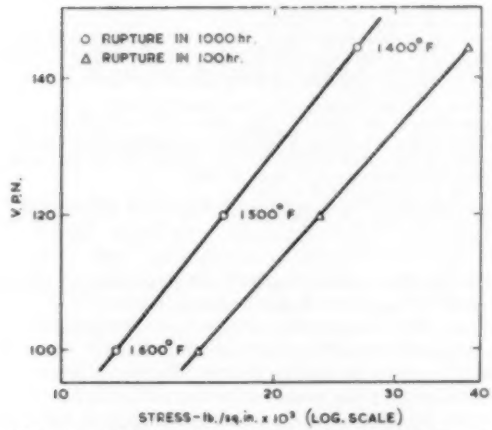

Fig. 10.—Relationship between hot hardness and rupture stress for superalloy S816.

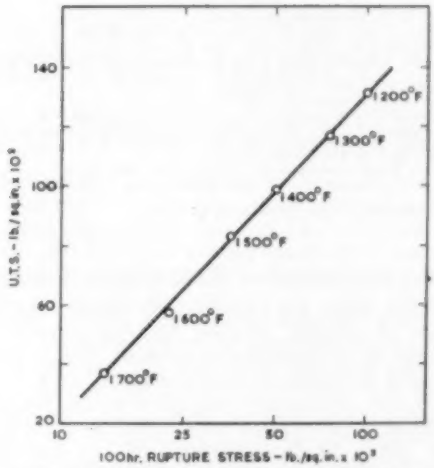

Fig. 11.—Relationship between ultimate tensile stress and 100 hr. rupture stress for Ni-Co-Cr alloy.

Results for Allotropic Changes

The adaptation of hot hardness testing to predict the different strengths of allotropes of a metal may be realised by a comparison of results on various phase transformations.

Chubb[24] has shown that the change α-iron (b.c.c.)→ γ-iron (f.c.c.) is accompanied by a 2·5-fold increase in V.P.N. The authors' unpublished work on low carbon steels gives a similar value of 2·5—3. Griffiths and O'Neill[2] have shown the same increase when δ (b.c.c.)→ γ (f.c.c.) manganese. Sherby and Lytton have argued from diffusion data that the increase in creep rate of iron on transforming from γ to α should be about 350 times. It has been shown that creep is related logarithmically to hardness, and log. 350 is 2·54, which agrees with the extent of the hardness change.

The b.c.c.→ c.p.h. change in thallium, titanium and zirconium is accompanied by hardness increases of 3·3-, 2·8- and 3·5-fold, respectively.[24] Lunsford and Grant[25] have given results for arc melted iodide titanium which show that at the α (c.p.h.)→ β(b.c.c.) transformation the 0·1 hour rupture test, i.e. in effect a straight tensile test, changes by a factor of 3·3, which again agrees well with the hardness changes.

From these results it appears that hot hardness tests not only indicate the direction of the change in strength, but may even predict the magnitude of the change. Such tests would have interesting application to plutonium, where the δ cubic phase has a negative coefficient of expansion.

Discussion

The relation between hot hardness and the high temperature load-bearing characteristics of metals and alloys has been shown empirically, but a more fundamental correlation would be facilitated by the use of a standard testing procedure. It is foreseeable that the rapid sorting and rejection of unlikely creep resistant materials by adopting the hot hardness test could become routine works practice. The situation is aptly summarised in the words of Ham[26] who, looking back on the development of molybdenum and its alloys, concluded " of the various tests applied, one of the simplest and most useful has been the Vickers hot hardness test . . . At least it can be shown that high hot hardness is a necessary —if not sufficient—property for good load-carrying capacity at high temperatures."

The industrial applications of hot hardness testing present great scope. Its obvious use to determine optimum hot working temperatures has already been exploited by Chubb and others in the U.S.A. The same team has shown its value for making an initial survey of the properties of a new alloy system. This has its obvious advantages now that nuclear power projects may use expensive metals which were not previously considered for structural work.

It must be emphasised that so far the Vickers hot hardness procedure only gives one point on the full load-strain deformation curve and does not indicate the slope of this curve and consequent work-hardening or work-softening effects. The equivalent of Meyer and Hargreaves analysis by ball tests at various loads and temperatures might provide still more information for working below the recrystallisation temperature of the metal.

Acknowledgment.

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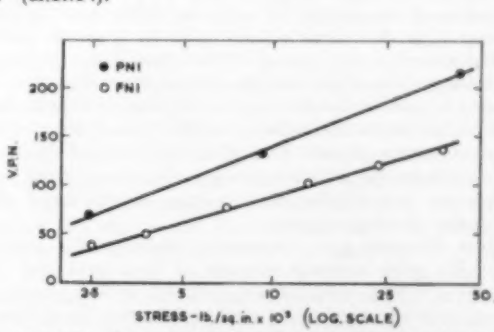

Fig. 12.—Relationship between hot hardness and 1,000 hr. rupture stress for two spheriodal graphite cast irons.

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New Aluminium Extraction Process

ALUMINIUM, LTD., has approved the construction of new facilities at Arvida, Quebec, for the production of aluminium by a basically new process. The process has been under development by the company for some years through the laboratory and pilot plant stages. It employs, as its principal raw material, bauxite of roughly similar grade to that required by the conventional process for the production of commercial aluminium. The new process does not appreciably reduce the large power requirement which is an outstanding characteristic of the conventional process. It does, however, give promise of substantial savings in other elements of production cost and in the investment required per ton of capacity.

The new facilities, designed as an experimental unit, will have a capacity of 6,000 to 8,000 tons of aluminium per year. They will be operated primarily for the purpose of confirming the conclusions already reached concerning the production costs obtainable with the new process. The capital cost of the new facilities will be of the order of $4 million, and it is expected that they will be available within two years.

The new process is covered in a large number of countries by patents held by Aluminium, Ltd.

Furnace Atmospheres from Blast Furnace Gas

THE Gas Atmospheres Division of the Incandescent Heat Co., Ltd., has announced a new process for the low cost production of nitrogen/hydrogen mixtures from blast furnace gas. Hy-Nitrogen (sometimes termed HNX), consisting of nitrogen with 1–7% hydrogen, is finding increasing use in the heat treatment of steel strip and sheet. The gas provides a truly inert atmosphere for bright annealing, and does not form soot during cooling, since it contains carbon monoxide. Hydrogen is present in sufficient quantities to combine with any oxygen leaking into the furnace and also to prevent water vapour from causing bluing. The demand for this type of atmosphere has led the Gas Atmospheres Division to develop a process with very low operating costs; the basic utilities cost less than one shilling per 1,000 s.c.f. of prepared atmosphere. The plant is designed for continuous operation with a minimum shut-down time, and coolers are suitable for maintenance on the water side whilst the plant is running.

Blast furnace gas (containing about 30% carbon monoxide with a small amount of hydrogen and the balance nitrogen and carbon dioxide) is first partially burned through a specially designed burner firing into a well insulated refractory lined chamber. From here the gases pass through a heat exchanger and cooler to reduce the temperature to within a few degrees of ambient. Carbon dioxide is then removed through a highly efficient absorber of unique design, using monoethanolamine solution. The composition of the gas leaving this unit is approximately within the following limits: nitrogen 93–99%, carbon monoxide 1–7%. Steam is introduced at this stage and the gases are preheated prior to entering the shift reactor, where carbon monoxide is converted to carbon dioxide and an equivalent volume of hydrogen is produced. After removal of the carbon dioxide in a second absorber—again using monoethanolamine—the wet hydrogen/nitrogen mixture leaves the plant. Final drying may be effected to any desired level by cooling the gas through a refrigerator unit followed by passage through an Incandescent dessicant-type Hydromaster dryer.

The whole plant is designed for operation with the minimum of attention; the part time services of one man should be sufficient on all sizes. Basic designs now available cover 10,000, 25,000, 50,000 and 100,000 s.c.h.f. units. The Gas Atmospheres Division will however prepare schemes for any size of installation to meet customers' requirements. The introduction of this equipment will be of great importance to many steel works where there are increasing demands for coke oven gas. Blast furnace gas may now be used for all atmosphere production, thereby reducing the consumption of coke oven gas normally used for this purpose.

Vickers-Armstrongs Press Agreement

VICKERS-ARMSTRONGS (ENGINEERS), LTD., have been manufacturing large mechanical and hydraulic presses at their Newcastle works since 1946 to the designs of the Clearing Division of United States Industries, U.S.A., and as a result of an extension to this agreement, which has just been concluded, the company's Crayford works are now to manufacture a range of Clearing open-backed inclinable Torc Pac presses of 22-ton, 32-ton and 45-ton capacity. The sale in the United Kingdom of Clearing presses manufactured by Vickers-Armstrongs (Engineers), Ltd., is handled by the Rockwell Machine Tool Co., Ltd., Welsh Harp, Edgware Road, London, N.W.2.

Forging Plant for Ulster

THE HUGHES TOOL CO., LTD., the Texas oil-well drill bits manufacturers, are now contemplating an important addition to their production equipment at Castlereagh, Belfast, including setting up a forging plant in a new building of 10,500 sq. ft. adjoining the existing factory. While direct employment in the forging shop will be small, it will greatly assist in increasing the company's productive capacity. At present Hughes Tool import forgings from Great Britain from which to produce 150 different sizes and types of rock bits. The Castlereagh forging shop will have a 1,600 ton Ajax press and other equipment.

Consulting Engineers' Centenary

Sandberg Patents in Permanent Way Engineering

PERHAPS the most spectacular achievement of Messrs. Sandberg, the London firm of consulting engineers, which recently celebrated its centenary, was the salvaging after World War I of the £1 million worth of gold from the P. & O. liner *Egypt*, which was sunk off Brest in 70 fathoms. It took several years to locate the wreck with the equipment available at the time, and a further three years to cut through individual decks by means of explosives before the roof was finally blown off the bullion room and the entire contents recovered, a device similar to a vacuum cleaner being used to collect the last loose sovereigns.

The more prosaic side of the firm's activities has been concerned particularly with railway engineering, one of the main interests of the founder, Christer Peter Sandberg, who was born at Venersborg in Sweden, in 1832. After completing his education in Sweden, he gained practical experience in the iron works of that country and in other parts of Europe, later acting as manager of several establishments. He founded the firm of Messrs. Sandberg in London in 1860, and in that year received his first appointment as consulting and inspecting engineer in England for the Swedish State Railway, a position which he held until his death in 1913. He established a general railway consulting practice, especially in connection with permanent way material. This grew to include many British, colonial and foreign railway authorities, and in recognition of his services, he received decorations from Sweden, France, Belgium, Russia and China.

By virtue of his metallurgical knowledge and special study of the subject, C. P. Sandberg acquired world-wide recognition as an authority on rail steels and permanent way engineering. His investigations led him to introduce many improvements in the design and manufacture of rails. The Sandberg sections were first brought out by him in 1878, and their later modifications in 1894 were universally adopted at that time.

In due course he took into partnership his three sons, Christer Peter Sandberg, Oscar Fridolf Alexander Sandberg and Nils Percy Patrick Sandberg. The three brothers continued the railway practice and in particular the work on rails. The sorbitic process for the heat treatment of rails was introduced, which consisted basically of spraying the head of the rail, whilst still red hot from the mill, with an air/water mixture: this treatment produces a hard wearing surface without affecting the ductility of the main body of the section. A further development, the Sandberg oven, was introduced later for the prevention of cracks by controlled cooling after rolling. This treatment proved remarkably effective, particularly in the United States, where, in one year, almost 44,000 rails were removed from the track due to transverse fissures. Since the introduction of controlled cooling a total of less than ten transverse fissure failures in controlled cooled rails has been reported in the last twenty years. In 1950, Mr. A. C. E. Sandberg, son of Alec Sandberg, joined the firm at a time when, due to the death of the three brothers, the absence of Chinese work, and the loss of British Railways contracts, due to nationalisation, there was a need for new ideas. The plan was developed of offering specialised consulting, testing and inspection services in the fields of metallurgy, welding, chemistry and concrete, it being considered that these services would be of value to consultants, contractors and manufacturers alike, who might not have normally available the specialised knowledge or equipment required. The laboratories, which had hitherto only been for metallurgical purposes, were completely equipped to cover these new fields, and this section of the firm has built up very satisfactorily over the last ten years.

Thus the firm now provides an inspection service with engineers resident throughout this country, the continent of Europe and the U.S.A. Contracts for the specialist consulting and laboratory services include co-operating on the concrete aspects of the new Forth and Severn road bridges, Park Lane improvements and the Hammersmith flyover. Welding supervision contracts include Shell's new office block on the South Bank and Victoria Tower for the Ministry of Works. Overseas work on the concrete side includes the reconstruction of H.M. dockyard, Malta, and Wairakei "B" power station in New Zealand, the development of the welding facilities of the Sudan Railways and welding and concrete contracts in the Persian Gulf. The firm is also engaged in the metallurgical and concrete aspects of ten atomic energy reactors for the A.E.R.E. and C.E.G.B., and is carrying out basic research into shielding concretes and gas-tight concretes, and experimental work for R.A.E., Farnborough.

News in Brief

FOUR leading metal companies, Aluminium, Ltd., Bridgeport Brass Co., Cerro De Pasco Corp., and Scovil Manufacturing Co., are to build a new hot rolling mill to supply aluminium re-roll stock for their respective sheet mills. A new corporation, to be owned jointly by the four companies and to be operated by Aluminium, Ltd., will build a semi-continuous hot rolling mill with an initial annual capacity of 100,000 tons and involving a capital investment of about $30 millions. It will be located in the North Eastern United States convenient to all four of these plants, and will have remelt facilities to handle scrap from the participants and their customers. Construction is expected to take about two years.

DAVID BROWN INDUSTRIES, LTD., and E.M.I. Electronics, Ltd., have been engaged for some time in a joint programme of research and development into the problems of applying electronic techniques to machine tools. The first fruits of this collaboration were shown in the electronically controlled gear hobbing machine exhibited at the Machine Tool Exhibition last June. It is planned to develop other complete machines as well as devices and mechanisms for control and inspection which will be available to machine tool manufacturers.

Cold Forging of Steel

"COLD forging of steel is the production method of the future, because it saves material and production time and therefore labour costs", said Dr. Ing. H. D. Feldmann, a recognised world's authority in the cold forging technique at a three-day conference on "Cold Extrusion of Steel" held in the City Hall, Sheffield, at the end of November. The conference, arranged by the Institute of Sheet Metal Engineering, was attended by over three hundred industrialists, reflecting the growing interest in the United Kingdom in exploiting this process, but its acceptance is slow compared with that in Germany.

Dr. Feldmann, technical director of Cold Forging, Ltd., a member of the Camp Bird Group, has been connected with cold forging of steel from its infancy in Germany. He joined the Camp Bird Group in 1959 as technical director in charge of the cold forging organisations of the Group in the United Kingdom and Germany. At the end of 1960 he was due to become also the joint managing director of the Group's new factory, SaarLandische Werkzeug- und Maschinenfabrik in the Saar, the first establishment in the world to manufacture complete cold forging installations.

Suitable for Large Quantities

In the first of his two lectures entitled "Economical Use of Cold Forged Components", Dr. Feldmann said that mass production of today encourages the use of the cold forging process—too small quantities inhibit its use. Therefore, standardisation of components, even of different firms, can improve this position as is being done already in the United States and Russia. Europe needs to employ these methods in order to remain a competitor. If all car manufacturers agreed to a standardisation of certain parts, which they all need, it would be possible to produce these parts much more economically than at present.

Referring to the sequence of operation in the technique of cold forging, Dr. Feldmann said that it is comparatively easy to develop a cold forged component, and maybe to produce several hundred, but to develop a cold forged component such that it can be made in mass production, i.e. in many thousands with an economic tool life, has caused many people to fail, and requires considerable knowledge of the theory. "We have now produced fundamental theory", continued Dr. Feldmann, "from which even untrained personnel are capable of determining the initial sequence of operations. It is now only necessary that the final stages of operations be calculated by an experienced specialist. By this means the high development costs of cold forged components can be considerably reduced."

Complete Installations Marketed

In his final lecture which concluded the Conference Dr. Feldmann discussed the development and present position of installations for cold forging. He emphasised the need to design machines to the requirements of cold forging techniques, and to study the characteristic work diagrams of these machines. To meet this demand for specialised equipment his group have designed and are marketing the world's first complete cold forging installation, comprising machines for the preparation of the slug, intermediate treatments, e.g. surface treatment including phosphating and lubrication of the preforms, and machines for various cold forging operations under the name Colforg. A complete plant which was sent and shown at the recent Hanover Machine Tool Exhibition has been re-installed for operation at Cold Forging, Ltd., Sunbury-on-Thames, Middlesex.

Vitreous Enamelled Aluminium

ONE of the latest and most interesting developments in the vitreous enamel industry is the enamelling of aluminium. During the past two years this process has become established commercially in Great Britain and a considerable growth in the use of vitreous enamelled aluminium, particularly in architecture, is foreseen in the future. As part of its programme in promoting the use of vitreous enamel and maintaining high standards for the industry, the Vitreous Enamel Development Council has just published a tentative commercial specification for vitreous enamelled aluminium for architectural applications. This follows up the V.E.D.C.'s recommended standards and general specification for vitreous enamel now included in the brochure "Vitreous Enamel in Architecture."

As aluminium melts at 650° C., which is lower than the firing temperature of steel enamels, new frits (the crystalline substance from which vitreous enamel is made) have been developed, thus making possible the process of enamelling aluminium. Vitreous enamelled panels have been used on buildings in the United States for over ten years. During 1957, 5 million sq. ft. of aluminium was coated with vitreous enamel, and the figure forecast for 1961 is in the region of 23 million sq. ft.

In this country practical applications of vitreous enamelled aluminium are starting to appear. The main use is in architecture, internal as well as external, for curtain wall infill panels, partition panels, wall tiles and decorative trim. It is, however, also very suitable for other uses, such as road and advertising signs and domestic appliances. Vitreous enamelled aluminium hollow-ware is already on the market. Vitreous enamel enhances the good features of aluminium. It adds colour in an almost unlimited range; it maintains its original appearance over long periods; it is simple to clean. It is also light and easy to handle and can be sheared or cut with practically no serration of the edges.

Crane Order

A £50,000 contract for the supply and installation of overhead cranes has been placed with The Wharton Crane & Hoist Co., Ltd. (Reddish, Stockport) by James Booth Aluminium, Ltd. The equipment will be installed this year in the company's Kitts Green Works, Birmingham, which is now being modernised and re-equipped as part of a £5 million expansion programme. The contract includes a 110-ton capacity, four-motor cage-controlled, overhead electric travelling crane, with a span of 62 ft. 10 in., which is fitted with a 5 ton auxiliary hoist. A change speed gear on the main hoist gives treble hoisting speed when lifting loads to a maximum of 37 tons. The contract also includes a 5 ton enclosed type crane, on a span of 49 ft., fitted with a telescopic mast and electric slewing gear, with automatic tongs for handling aluminium ingots. The third major item is a 30 ton, two-point lift, three-motor, crane on a span of 91 ft. 3 in. This crane is also fitted with change speed motion to give a treble speed for 10 ton loads.

Low Nitrogen Converter Steel

Important S.C.O.W. Development

THE comparatively high nitrogen content of steel made by the conventional Bessemer process makes sheet rolled from it unsuitable for severe pressing or drawing operations. The nitrogen is picked up from the air blown through the metal in this process, and even the use of an oxygen-enriched air blast cannot achieve the very low nitrogen content required in steels for this class of work. In view of the increasing demand for such steels, the Steel Company of Wales decided some three years ago to build a plant for their production, and after a survey of the possible methods chose the steam-oxygen bottom-blown process as being a high-rate producer of low-carbon, low-nitrogen steel of deep-drawing quality.

Improved Bottom Life

At the time, the process was in operation on the Continent, where the largest size converter had a capacity of 15 tons. Even at this size, there were difficulties in maintaining the converter bottom in good condition, difficulties which were overcome by introducing a little air into the blast. This would also introduce a little nitrogen into the steel, but much less than with even an oxygen-enriched air blast. At the Abbey works the bold step was taken of building the new plant without an air blower, so that the introduction of nitrogen from this source is impossible. Furthermore, because of the high output required from the plant, three vessels of 50 tons capacity were installed. Not unexpectedly, when the plant came into operation difficulties were experienced in that the bottom lives were extremely short. Continental experience was unavailing as it was based on the introduction of air into the blast, and was, moreover, confined to converters of 15 tons maximum capacity. After considerable experiment, a solution was found in a new bottom-making technique in which the refractory material was poured into the bottom former as a slurry, instead of ramming it in as a paste. This procedure, combined with a change in the subsequent baking, completely overcame the furnace bottom maintenance problem.

Thus, the view that steels could be made economically by the steam-oxygen process without the introduction of air has been proven, and, as theoretically anticipated, large quantities of oxygen-steam steel have now been used with complete success on the most difficult drawing operations known to the press shops. This is not altogether surprising as the process produces, as a matter of course, steels which only contain one-third of the nitrogen found even in open-hearth steel. Indeed it is claimed that the VLN ("Very Low Nitrogen") process produces steels containing less nitrogen than those produced by any other known steelmaking process. The average content is 0·0012%, with some heats containing only 0·0008% nitrogen.

The fact that the VLN process is primarily a user of molten pig-iron instead of scrap results in a very low content of "tramp elements" (nickel, copper, chromium and tin), which again contributes to the ductility attainable. Temperature of the charge during blowing can be precisely and instantaneously controlled by adjustment of the steam/oxygen ratio—a further improvement which can only be achieved in other processes by more laborious methods such as, for instance, the addition of scrap in order to reduce the temperature.

Use of Scrap

Although generally regarded as unsuitable for the use of scrap, the process is capable of some modification and experiments using lower steam contents in the blast have shown that it is possible to operate with 15% of scrap—with, of course, increase of "tramp elements."

The Steel Company of Wales is confident that the VLN process, both in theory and practice, offers a steel consistently equal in ductility to the best that can be achieved by any other steelmaking process. As evidence of this confidence, the fourth 50 ton vessel envisaged in the original plan for the plant is to be installed shortly, to bring the weekly production up to 19,000 tons.

Swedish Aluminium Expansion

SVENSKA METALLVERKEN, Sweden's leading producers of non-ferrous metal products, are to carry through a major expansion of their Finspång works. Under the scheme the productive capacity for aluminium semi-manufactures will be increased from 20,000 tons to 20,000 tons per annum for rolled products and from 2,500 tons to 3,500 tons for pressed products. The programme, which will also include an extension of the smelting works, is to be carried through during a three-year period at an estimated cost of Kr.15,000,000 (£1,035,000). It will require an increase in the labour force of about three hundred men.

The increase in capacity now decided on is based on a forecast for the consumption of aluminium in Sweden indicating a 10% rise per annum over the next few years, the company says. The potentialities of increasing exports, particularly after the establishment of E.F.T.A., point in the same direction. To meet the increasing demand for aluminium in the building industry, a new plant for chemical surface treating of sheets is scheduled to go into full operation next year.

Negretti & Zambra in Newcastle

THE time is past when instruments were watchdogs keeping an eye on an adequate number of skilled operators. They are now the heart of the process, and in many cases it would be difficult, if not impossible, to continue efficient operation in the event of breakdown of any part of the instrumentation. It is with the object of improving their service to industry in the North of England that Negretti & Zambra have opened a Newcastle branch. This will act as technical sales office, service depot, supplies depot and retail shop—the last named handling such items as household barometers, binoculars, microscopes, drawing instruments, etc.

New Look for B.O.C.

THE British Oxygen Co., Ltd., resumed trading under its own name on 1st October and on 31st December, 1960, the following companies ceased to operate: British Oxygen Gases, Ltd., British Oxygen Engineering, Ltd., British Oxygen Research and Development, Ltd., Quasi-Arc, Ltd., Sparklets, Ltd., and A. Charles King, Ltd. All current trade marks and trade names will continue to be used.

The following divisional chief executives will be members of the executive management board responsible to MR. T. E. POTTS, managing director, The British Oxygen Co., Ltd.: finance, MR. L. S. KINNEAR; administration, Mr. F. C. S. LEWIN-HARRIS; sales, MR. J. STRONG; engineering, MR. R. J. BARRITT; operating, MR. R. H. REYNOLDS; technical, DR. N. GROSS; scientific, DR. N. BOOTH; chemicals, DR. R. F. GOLDSTEIN; overseas, MR. R. C. HESKETH-JONES.

The reorganisation is designed to re-align the wide activities of the group in the U.K. in the most effective pattern. Two new divisions are set up as part of the reorganisation. The first is the operating division which will operate all gas producing works in the U.K. (presently operated by B.O.G.) and the electrode manufacturing works at Bilston (Q.-A.). It will also be responsible for the distribution of products, for the maintenance of evaporators and pipelines in customers' works, and for transport. The second is the technical division. It is proposed to enlarge the technical centre at Cricklewood. This will now have enhanced importance concentrating on the development of products and processes and backing up the whole home and export selling effort.

The sales division will be responsible for all group selling activities in the U.K., excluding chemicals. As well as building air separation plants of all kinds and making all the company's equipment, the engineering division will be responsible for building, erecting and maintaining all gas producing plants in the U.K. for the operating division. This department will also be responsible for providing full engineering service to the operating division, including installation of major distribution systems. The scientific division—centred at Morden—will be responsible for all group scientific work.

The chemicals division will continue to be responsible for the operation and management of the three companies in the division, Odda Smelteverk A/S, Odda, Norway, British Oxygen Chemicals, Ltd., Chester-le-Street, and Carbide Industries, Ltd., Northern Ireland. The activities of the overseas division are being extended to cover all export trade other than chemicals. It will operate two departments, overseas (the operational link with all associated overseas companies), and export (responsible for all sales to associated companies and to agencies in other countries).

Corrosion Report

THE annual report for 1959 of the European Federation of Corrosion is now available (duplicated typescript, 143 pages, size DIN A 4). It has been edited, as in previous years, by the Frankfurt Office of the General Secretariat of the European Federation of Corrosion. The Federation, which had a membership of fifty-two societies from seventeen European countries at the end of 1959, can look back on another year of satisfactory development. Progress has been reflected particularly by the number of meetings at a European level, which increases every year. These meetings attract scientists from all parts of Europe and provide the opportunity for a lively exchange of views.

The annual report is divided into three parts, which serve the following purposes. The first part presents the report of the General Secretariat and gives an account of activities within the Federation; the second part contains reports from member societies on their technical work in the field of corrosion; and the third gives a survey of the institutes and research centres in individual countries which are concerned with problems of corrosion and the protection of materials of construction. Thus, the Annual Report for 1959 of the European Federation of Corrosion provides specialists with valuable information on the technical work on corrosion which has been carried out in Europe with particulars of addresses and publications, research projects and papers read at meetings.

The report cannot be obtained through the book trade, but should be ordered from the General Secretariat of the European Federation of Corrosion, Büro Frankfurt (Main), Postfach 7746. The price to members of societies affiliated to the Federation is DM 15 (the name of the society should be given when ordering), and to non-members DM 30, including forwarding charges.

New Ingot Casting Process

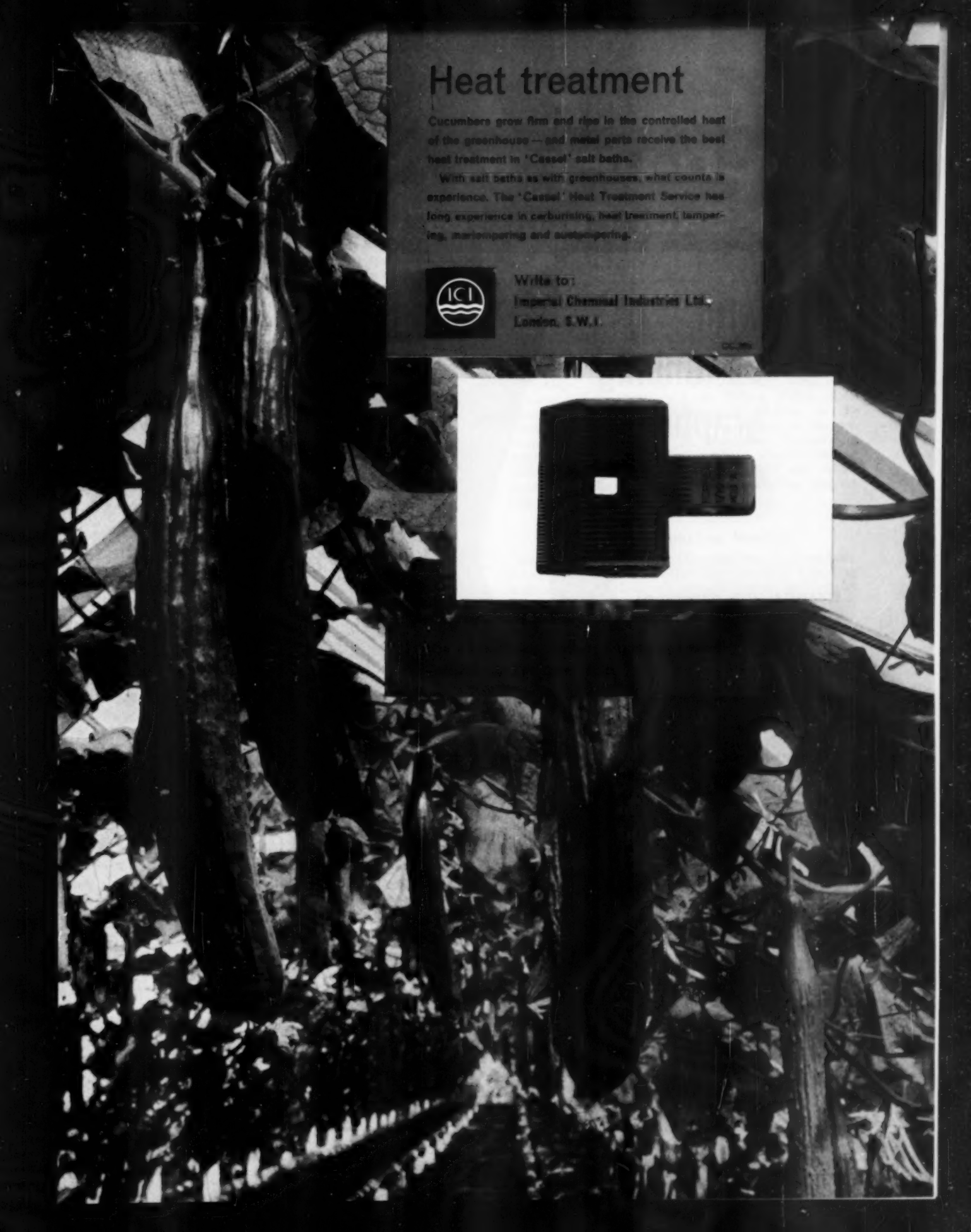
THE INCA STEEL CO., LTD., of Forncett Street, Sheffield 4, announce that, in association with Foundry Services International, Ltd., they are developing a process for the casting of ingots and other items, arising from an invention of Mr. W. Kelsey, a director of the former company. The process results in ingots having a homogeneous structure which is particularly applicable to the high-speed steels in that central carbide segregation is eliminated. At the moment development work on the process is still continuing, but it is hoped to release further details in the relatively near future. Ultimately, the technique will be made available to steel manufacturers in the U.K. and throughout the world by the companies within the Foseco Group.

Pyrometer Agency

INDUSTRIAL Instrument Services Co., pyrometer instrument manufacturers and suppliers, are the British agents for the sales and technical service of the Wheelco Instrument Division of the Barber-Colman Co., Rockford, Illinois, U.S.A. Their services include a repair and reconditioning service for all existing Wheelco pyrometer instruments, with a complete range of thermocouples to suit any type of instrument and application. They have recently moved to larger premises, the new address being Elkington St., Aston, Birmingham 6. (Tel: ASTon Cross 2771).

Change of Telephone Number

As a result of the transfer of the offices of The Telegraph Construction and Maintenance Co., Ltd. (a member of the B.I.C.C. Group), from Mercury House, Theobald's Road, to 21 Bloomsbury Street, W.C.1., the telephone number and inland telegraphic address are now MUSeum 1600 and Telcon Phone London, respectively.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NEWS AND ANNOUNCEMENTS

United Steel Top 3m. Tons

For the first time in the company's history, annual steel output of The United Steel Cos., Ltd., has exceeded three million ingot tons, while pig iron production was over two million tons, also for the first time. The 1960 production figures reveal record outputs of coke, ironstone, pig iron and steel. At the Samuel Fox branch, ingot steel output has topped the 400,000-ton mark for the first time, while Workington's steel output also set a new high level at over 300,000 tons. Pig iron production at Workington exceeded 500,000 tons for the first time, and coke production at Appleby-Frodingham was increased by over 125,000 tons during the calendar year. The company's Ore Mining Branch produced a new record tonnage of ironstone, beating the 1959 figure by 470,000 tons.

Evening Courses in Welding Technology

The School of Welding Technology will be organising evening courses in Birmingham and Manchester in the Spring of 1961, the subjects being: Birmingham—Detail Design of Welded Structural Steelwork; Manchester—Design for Welding in Heavy Engineering. These courses are intended for designers and draughtsmen who wish to acquire the specialised knowledge which is so important if the full advantages of welded construction are to be obtained.

Metal Physics Lecture

Professor W. Hume-Rothery, O.B.E., F.R.S., of Oxford University, is to give a lecture on "The Theory of the Alloys of Copper" under the auspices of the Metal Physics Committee of The Institute of Metals. The meeting will take place at the Royal Institution, Albemarle Street, London, W.1, on Thursday, 23rd February, 1961, at 6.30 p.m. Visitors are welcome; tickets are not required.

Croxson Memorial Lecture

The Society of Non-Destructive Examination announces that the first Croxson Memorial Lecture, in commemoration of the late Mr. Charles Croxson, founder chairman of the Society, will be presented on Friday, 17th February, 1961, at 6.15 p.m., in the Caxton Hall, Westminster, by Dr. L. Mullins, on: "The Evolution of Non-Destructive Testing." Admission to the Lecture will be by ticket only: applications for tickets—not more than two per applicant—and for further details of the lecture, should be addressed to the honorary secretary, Mr. D. T. Carter, E.S.A.B., Ltd., Gillingham, Kent.

Extra Induction Heating Course

Due to the exceptional response for the Induction Heating Course advertised for February, 1961, the Process Heating Division of Pye Ltd., are inserting an extra course before that to be held in May after the normal interval. This additional course will again be held at the Globe Hotel, Hills Road, Cambridge, commencing at 2 p.m. on Tuesday, 7th March, 1961, and finishing at 5 p.m. on Wednesday, 8th March, 1961. The subjects to be covered will be identical with those in the February course. Further details may be obtained from Mrs. E. Rayburn, Pye Process Heating, 28 James Street, Cambridge.

Metal Structure Lectures

Organised by the University of London, a course of three lectures on "The Electronic Structure of Metals" will be held in the new physics building of Imperial College of Science and Technology at 5.30 p.m. in Thursdays, 2nd, 9th and 16th February, 1961. The lecturer will be Professor A. B. Piffard, F.R.S., John Humphrey Plummer Professor of Physics in the University of Cambridge, and the chairman at the first lecture will be Professor M. Blackman, Professor of Physics in the University of London. The lectures are addressed to students of the University and others interested in the subject, and admission is free, without ticket.

Lilleshall-Spartan Venture

The Lilleshall Co., Ltd., and Spartan Steel & Alloys Ltd., following a considerable period of technical co-operation in the field of stainless steel rolling technique, have agreed to form a joint company in which they are equal partners, to consolidate and extend their interests in steel rolling. The arrangements will ensure the continuity of supply of their full range of rolled steel products to all Lilleshall and Spartan customers. The new company, will be concerned solely with orders for hire rolling of stainless and alloy steels. The mild steel section business will continue to be handled by The Lilleshall Co., Ltd., exactly as at present.

John Brown German Agreement

John Brown & Co., Ltd., announce that their subsidiary company, John Brown (S.E.N.D.), Ltd., have concluded an agreement with Demag A.G. Duisberg for the manufacture and supply in the United Kingdom of a wide range of iron and steel works plant to Demag designs. John Brown (S.E.N.D.), Ltd. is the organisation in the John Brown group which undertakes the designing and contracting for engineering products which are new to the John Brown subsidiaries, and co-ordinates the manufacture of these new products amongst their appropriate works.

AEI Order from Australia

Australian Electrical Industries (Pty.), Ltd., have ordered from the Heavy Plant Division of Associated Electrical Industries, Ltd., synchronous and squirrel-cage induction motors valued at over £100,000 to drive compressors in a new tonnage oxygen plant in New South Wales. The plant, which is being supplied by Linde Eismaschinen A.G., of Munich, will produce oxygen in large quantities for steel manufacture.

Three 3,500 h.p. synchronous motors will be used to drive centrifugal air compressors; two 2,200 h.p. synchronous motors will drive centrifugal oxygen compressors; and two squirrel-cage induction motors of 1,500 h.p. will drive reciprocating oxygen compressors. Starting equipment and switchgear are included in the order.

Tonnage Oxygen for Steel, Peech & Tozer

TONNAGE Oxygen is to be supplied to the Rotherham works of Steel, Peech & Tozer (branch of The United Steel Cos., Ltd.) by The British Oxygen Co., Ltd. The supply will meet the requirements of Steel, Peech & Tozer's new electric arc furnaces to be installed in their Templeborough melting shop under the current development programme. B.O.C. are already extending the liquid oxygen manufacturing plant at their Brinsworth works and to meet this new demand they will now add a 100 tons a day tonnage oxygen plant at Brinsworth. The oxygen will be piped from Brinsworth to Steel, Peech & Tozer's Rotherham works, which are about half-a-mile away. The installation of this large plant will provide cheaper oxygen gas in the heart of the Sheffield-Rotherham area and brings the time nearer when pipeline supplies can be made available to other major users in this important industrial area.

Firth Cleveland Steels, Ltd.

THE Firth Cleveland group has formed a new company—Firth Cleveland Steels, Ltd.—with registered offices at Wentworth Street, Sheffield. According to a statement by the managing director, Mr. J. Tonking, the company has been set up with the object of ensuring that the customers of J. J. Habershon and Sons, Ltd., The Tenuous Steel Co., Ltd., and Firth Cleveland Steel Strip, Ltd., reap the benefits of the potential of these companies which are now operating in the closest touch with each other to provide a wide range of specialist steel strip. Orders placed with the three companies will continue to be executed by them as separate manufacturing companies and there will be no break in continuity of association between customer and the individual companies concerned.

The three companies will pool ideas, skills and development work with a view to improving product qualities and introducing new products. Steps have been taken to increase the production of high carbon steel strip, and plans are advanced for considerably stepping up the quantities of cold rolled stainless steel strip. To look after the interests of the small user of steel strip, Habershons have set out a special stockist small order department.

Vacuum Brazing Furnace Order

AN order for a high vacuum brazing furnace worth more than £7,500 has been placed with Vacuum Research (Cambridge), Ltd., by the Admiralty. It will be an electric resistance heated unit capable of being evacuated to less than 10^{-4} mm. mercury, and it will be possible to maintain a temperature of 1,300°C. in the 2 ft. long x 1 ft. square hot zone. Temperature measurement will be by three flexible thermocouples capable of being taken to any section of the hot zone and two further thermocouples to indicate the temperature of the heaters, a continuous record of pressure and temperature being provided by a six point recorder. A shielded window will enable the operator to view specimens within the furnace. All the furnace controls will be power operated and interlocked against failure of mains services.

West Instrument in Germany

WEST INSTRUMENT, LTD., have appointed Dr. Hanns L. Mennicken as executive in charge of the new West sales and service organisation in Germany. West Instrument, which is associated with West Instrument Corporation in the U.S.A., is supplying its Gardsman temperature control instruments to a number of leading German manufacturers and intends to enlarge its scope considerably in the coming year in the plastics, metallurgical, research and general engineering fields. Dr. Mennicken will operate from: 22a Krefeld/Ndrrh., Hanninxweg 38, West Germany. (Tel. Krefeld 31434u. 31446).

Two-Century Family Connection Broken

AFTER having served The Sheffield Smelting Co., Ltd., for forty-seven years, thirty-six of them as a director, Mr. Ronald E. Wilson, M.C., J.P., retired on 31st December, 1960. The board and company is now without a member of the Wilson family or its forbears for the first time in two hundred years, the business having been founded by John Read, an ancestor of Mr. Wilson, in 1760. The company started as a very small concern but today, as refiners and suppliers of the precious metals in a multitude of fabricated and semi-fabricated forms for industry and the arts, it enjoys world-wide repute. To mark the bi-centenary of the business Mr. Wilson has just published a book entitled "Two Hundred Precious Metal Years." Besides describing the history of the business through many generations of his family, the volume contains much material of sociological interest.

Johnson, Matthey in Sweden

JOHNSON, MATTHEY & CO., LTD., have acquired a controlling interest in the Swedish precious metal company A.B. Gösta Nyström of Stockholm. Mr. Gösta Nyström, who founded the business in 1917, has retired and a new board has been appointed consisting of four Swedish and two British directors, with Mr. Ove Trulsson as chairman. A.B. Gösta Nyström supply precious metal products for all industrial purposes as well as for jewellery, silversmithing and dental requirements. Since 1932 they have acted as agents in Sweden for some of the products of Johnson Matthey. The company will in future be known as A.B. Nyström & Matthey.

The New Bluebird

WHEN Donald Campbell arrived at London Airport on his return from the U.S.A. after his crash on Bonneville Salt flats, he announced that plans to rebuild his £1 million Bluebird were already under way. "It will be exactly the same as the prototype," he said, "because the only reason I crashed in September was because of the surface conditions at Bonneville Salt Flats and for no

other reason. The machine itself was a magnificent feat of British engineering."

The British Aluminium Co. has fabricated duplicates of all the machine's aluminium components and they are already in the hands of Motor Panels, Ltd., the builders of Bluebird. The whole of the aluminium sheeting has been specially rolled at the B.A. Falkirk mills. "I undoubtedly owe my life to the amazing strength of the metal," said Campbell, "and I am quite convinced that it cannot be bettered in any way." For the body skin and the pressurised chamber containing the gas turbine, an alloy of aluminium and magnesium has again been used, and most of the castings, including the gearbox, are also of aluminium alloy supplied by the Wednesbury foundry of Williams Mills, Ltd.

Efco Furnaces, Ltd.

THE ELECTRIC RESISTANCE FURNACE CO., LTD., a member of the Efco group of companies, has changed its name to Efco Furnaces, Ltd. The change became desirable due to the increased scope of the company's interests, which were originally confined to electric resistance heating but have in recent years been widened to include both gas- and oil-fired furnaces.

Castrol Industrial, Ltd.

WAKEFIELD-DICK INDUSTRIAL OILS, LTD., a member of the Castrol group, has been renamed Castrol Industrial, Ltd. This company is the Castrol group's United Kingdom marketing organisation for industrial, marine and electrical oils. Formerly known as W. B. Dick and Co., Ltd., it was reconstituted in 1956 as Wakefield-Dick Industrial Oils, Ltd. The further change of name follows logically upon that of the parent company from C. C. Wakefield and Co., Ltd., to Castrol, Ltd., last August.

Oxygen Lancing Solves Repair Problem

AN unusual application of oxygen lancing solved an urgent repair problem at the United Kingdom Atomic Energy Authority's nuclear power station at Chapelcross, Annan, Scotland, recently when difficulty in removing a seized stud bolt in the casing of a main blower threatened a costly delay in bringing the reactor back on load. The damaged stud bolt, 10 in. long, $1\frac{1}{4}$ in. in diameter, and made of high tensile steel, could not be removed from the main blower inlet flange. Until it was removed the blower could not be reassembled and this in turn delayed the restarting of the reactor and two turbo alternators after a maintenance shutdown. Attempts to remove the bolt by drilling were unsuccessful and a cutting specialist from The British Oxygen Co., Ltd., had to be called in. He carried out the intricate task using first a Saffire combined cutter with $\frac{1}{16}$ in. nozzle and then an oxygen lance fitted with a $\frac{1}{4}$ in. gas barrel. When the lancing operation was completed only slag remained in the pocket and this was easily removed by drilling to make way for the insertion of a new bolt.

£$\frac{3}{4}$ m. Steel Order from Mexico

IN the face of world-wide competition, Steel, Peech and Tozer, of Rotherham, a branch of The United Steel Cos., Ltd., have secured contracts to the value of £750,000 for the supply of railway axles and wheels to Mexico. Deliveries will be spread over about ten months and will provide useful work for certain departments which have been short of orders in recent months. These departments include the wheel mill and axle forge at Steel, Peech and Tozer and the machine shops at Owen & Dyson, Ltd. Orders of a similar magnitude were obtained from this highly competitive market about twelve months ago.

British Furnaces Kepston Division

BRITISH FURNACES, LTD., of Chesterfield, in association with Kepston, Ltd., of Kinross, have formed a Kepston Division of British Furnaces for the production of electric resistance furnaces to operate with controlled atmospheres, including hydrogen, nitrogen, argon and helium, for heat treatment and brazing operations on most metals, including stainless steels. Outstanding features claimed for the Kepston furnace include: absence of normal hydrogen hazards; controlled heating rates, from very slow to 100° C./min. up to 1,600° C.; controlled cooling from vacuum slow to 100° C./min. down to 450° C.; no restriction on size and shape of heating zone, from laboratory size upwards; and operations under visual control at all temperatures.

All electric resistance furnace enquiries will be handled by the Kepston Division of British Furnaces, Ltd., Derby Road, Chesterfield.

Personal News

MR. C. R. WHEELER, C.B.E. (chairman, Guest Keen Iron and Steel Co., Ltd., additional vice-chairman, Associated Electrical Industries, Ltd., and a director of The Steel Company of Wales, Ltd.) has succeeded MR. R. F. SUMMERS (chairman, John Summers and Sons, Ltd.) as president of the British Iron and Steel Federation. The Council of the Federation has signified its intention of appointing Sir Julian Pode (managing director, The Steel Company of Wales, Ltd.) as president-elect of the Federation for 1961.

MR. B. P. R. PARSONS, previously managing director of Bound Brook Bearings, Ltd., Lichfield, has been appointed chairman of the company. At the same time he has been made a director of the parent company, Birfield, Ltd. The previous chairman of Bound Brook, MR. H. E. HILL—who is also chairman of Birfield, Ltd.—will remain as vice-chairman. At the same time as these appointments, MR. T. L. MARTIN, formerly administration director, becomes director and joint manager (commercial) and MR. W. HARRIS, previously works director, is appointed director and joint general manager (works).

MR. J. A. METCALFE has joined the Board of Foseco International Ltd. A director of Minerals Separation, Ltd., and many other companies, Mr. Metcalfe has been a director of Foseco Holdings, Ltd., since 1st January, 1960.

IN order to cope with expanding business, Wild-Barfield Electric Furnaces, Ltd., have carried out some internal re-organisation and made some new appointments, all of which have been filled from within the company. MR. W. R. BREW, sales manager, who joined the company

in 1934 and has always been closely associated with its technical activities has been appointed executive manager (engineering). Another long service member of the staff, Mr. F. L. Gladwin, sales manager of the induction heating and vacuum divisions has been appointed executive manager (commercial), and Mr. O. V. Metcalfe, works manager since 1938 becomes executive manager (production). Mr. R. C. Ray, who has been with the company since 1937—apart from service with the R.A.F. during the war—has been appointed sales manager of the company and its subsidiary, The Applied Heat Co., Ltd.

The United Steel Cos., Ltd., announce that Mr. C. M. Slocombe will be appointed director of engineering of Distington Engineering Co., Ltd., from 1st April, 1961, and will relinquish his present post of director of engineering at Samuel Fox and Co., Ltd., on 31st August 1961.

Mr. W. E. Lambourn, joint deputy managing director of the Pressed Steel Co., Ltd., retired at the end of 1960 after more than thirty-four years of valuable service to the company. Mr. F. E. Cairns, (previously joint deputy managing director) now becomes deputy managing director. Other changes have been announced as follows: Mr. R. Craig becomes senior executive director; Mr. R. N. Davies becomes group director of manufacturing and a member of the main board of the company; Mr. S. C. E. Lewis becomes group supplies director and a local director; Mr. L. Long becomes deputy group director of manufacturing; Mr. S. A. J. Frampton takes over from Mr. Long as works manager, Cowley, and becomes a director of the car body division; and Mr. A. H. Pether becomes group tool manager, and a director of the car body division.

For reasons of health Mr. J. H. Russell has relinquished the position of managing director of Hall and Pickles, Ltd. He will retain his seat on the board and also on the boards of Hall Engineering (Holdings), Ltd., and the Improved Metal Label Co., Ltd. Mr. F. R. Robbins and Mr. A. M. C. Murphy have been appointed joint managing directors, and Mr. E. W. B. Davis general sales director.

Distington Engineering Co., Ltd., a subsidiary of The United Steel Cos., Ltd., announce the following appointments: Mr. A. G. Thorburn, machine shop manager, is now quality control engineer responsible to the general manager for all matters of quality control and inspection. Commander M. G. Lyne, quality control engineer, has become chief planning engineer responsible to the production manager (engineering) for planning, estimating, progress and shop loading and ancillary departments and Mr. J. Lowe, assistant machine shop manager, has been appointed acting machine shop manager.

The Wednesbury Tube Co., Ltd., Bilston, Staffs, announce that Mr. P. J. Custis and Mr. D. E. Drake, have been appointed directors, whilst still retaining their present posts of chief accountant and secretary, respectively.

The directors of Crofts (Engineers), Ltd., of Thornbury, Bradford, announce that, following recent alteration of the company's Articles of Association authorising the appointment of sectional directors, four executives of the company have now been so appointed. They are: Mr. E. J. Holdin, home sales director (previously general sales manager); Mr. F. Rotheray, overseas sales director (previously overseas sales manager); Mr. H. W. Cameron, London area director (previously London area manager), and Mr. A. Spencer, commercial director (previously commercial manager).

Mr. H. West, managing director of Associated Electrical Industries (Manchester), Ltd., has been appointed to the board of Associated Electrical Industries, Ltd.

Mr. T. E. Greenfield has been appointed sales development manager of the industrial process control division of Gresham Automation, Ltd., Gresham House, Twickenham Road, Hanworth, Middlesex.

Mr. H. M. Davis joined Southern Analytical, Ltd., as chief engineer and director in June 1960. He will be responsible for the design and development of all the chemical analysis instrumentation at present manufactured and contemplated for the future.

Mr. A. M. Dawson, development engineer of David Rowan and Co., Ltd., Glasgow, has been appointed assistant general manager of the Rowan subsidiary, Lancefield Foundry Co., Ltd.

Mr. A. Nadin, general manager, Brayshaw Furnaces, Ltd., and Brayshaw Tools, Ltd., has been appointed a director of both these companies.

Shell-Mex and B.P., Ltd., announce the appointment of Mr. A. C. Durie as general manager—industrial sales, and Mr. E. Rendall as assistant general manager, industrial sales.

Capt. J. K. Hamilton R.N. has been appointed a director of Sheffield Forge and Rolling Mills Co., Ltd.

Obituary

We regret to record the death of the following:

Mr. T. P. W. Norris, M.B.E., M.C., deputy chairman of George Kent, Ltd., who died on 21st November, 1960, as the result of a motoring accident. Mr. Norris, who lived at Redbourn, Hertfordshire, was sixty-eight years of age. He was born at Reading and educated at Rugby and New College, Oxford. Prior to joining the Kent board in September 1958, he was chief personnel officer to the Vickers group, and before that labour manager of the Billingham Division of Imperial Chemical Industries, Ltd. He was also a former president of the Institute of Personnel Management.

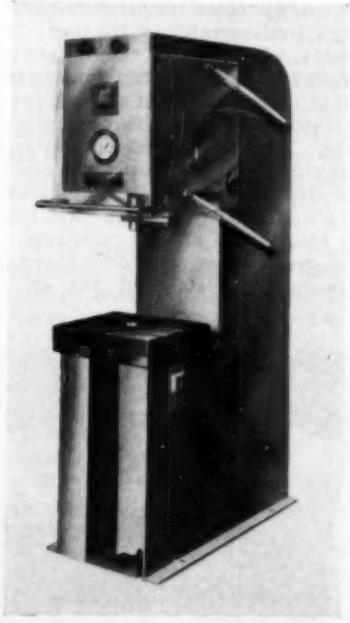
Dr. E. Voce, senior metallurgist to the Copper Development Association, who died on 26th October, 1960, at the age of fifty-eight. Dr. Voce, who was well-known to regular readers of this journal as the author of the annual survey of the copper and copper alloy field, was educated at King Edward's Grammar School, Birmingham and later at the University of Birmingham. After initial research at the University for the British Non-Ferrous Metals Research Association from 1924 to 1926, he took up an appointment with Barker & Allen, Ltd., where he stayed until 1930. Then followed a period of sixteen years on the staff of the B.N.F.M.R.A. before becoming senior metallurgist to the Copper Development Association in 1946. In the course of his work for the Association, Dr. Voce served on numerous British Standards Institution committees concerned with specifications for copper and copper alloy materials. One of his special interests, apart from his C.D.A. activities, was the mathematical treatment of the deformation of metals, on which subject he published several papers.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

High-Speed Hydraulic Presses

An entirely new range of high-speed hydraulic presses, known as R-G, has been designed and built for Dowding & Doll, Ltd. by Rhodes, Gill & Co., Ltd. The three models—with 5, 10 and 15 tons pressure capacity—are entirely self-contained, and the hydraulic reservoir, pump, motor, and all pipe-work and control rods are fully enclosed within a fabricated steel frame of exceptionally sturdy design. The R-G presses have been developed to simplify and speed up such operations as blanking and piercing, forming and bending, broaching, clipping, marking and assembly. On all three models, operating pressure and slow ram advance for setting are controlled by a regulator fitted close to the pressure gauge for which an isolating valve is provided. Both the ram nose and the table are designed to accept most existing tooling. Perspex guards provide a clear view of the work whilst affording complete protection to the operator.



The 5 ton model can be supplied either as a bench press or with a pedestal for floor mounting. Operation is by means of a hand-rail which extends across the front of the press—an arrangement which permits working with either hand. The pedestal model can also be supplied for foot operation. A unique accumulator system provides rapid ram approach with instantaneous speed reduction and the application of full operating pressure immediately the load is applied. The double-acting cylinder and ram provide positive power ram return. The ram is prevented from turning by a spring-loaded plunger housed within the frame. There is no obstruction of the table area and the stroke is readily adjustable. Pressure can be maintained for normal periods and simple special equipment is available to extend the duration of pressing. The speed of the ram on the approach, pressing and power return strokes is 1,000, 35 and 650 in./min., respectively.

Both the 10 ton and the 15 ton models operate on the jack-ram prefill system. A robust guide is fitted to check rotation of the ram. Compactly housed, it permits full use of the table area and does not foul the pillars of the die sets. A device can be fitted to limit the downward stroke which is readily adjustable by means of a knurled wheel projecting from the side of the press. The device permits extremely accurate inching of the ram. T-slotted tables are available for either model and a four or eight station automatic rotary indexing table can also be incorporated. Extra high-speed models are available. Speed of the ram on the standard 10 ton model is 390, 35 and 186 in./min. on the approach, pressing and power return strokes, respectively, the corresponding speeds for the 15 ton model being 390, 21 and 140 in./min.

Dowding & Doll, Ltd., 346, Kensington High Street, London, W.14.

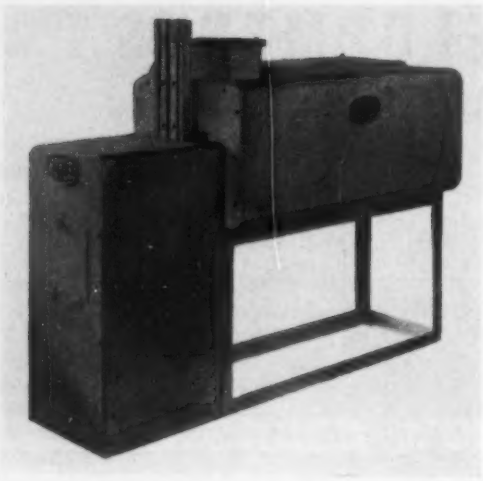
Heat Treatment Baskets

Supplementing its line of heat treating equipment, Ipsen Industries, Inc., has installed facilities to manufacture heat treatment baskets. They are designed primarily for use with controlled atmosphere and vacuum units. Standard sizes include a 22 in. width, 34 in. length, and 5 in. height; and a 28 in. width, 43 in. length, and 5 in. height. Special sizes are also fabricated, and tray height can range from 2 in. to 9 in. The basket consists of an Inconel tray and woven mesh liner. It offers maximum strength at elevated temperatures, and minimum thermal distortion. Openings in the basket permit maximum heating and quenching rates. These new trays are specially designed for stacking. The ends consist of a double loop and sleeve arrangement that locks the baskets and prevents any possibility of slipping. Loaded trays may be stacked and handled as a single unit for heating or quenching operations. Pressure resistant welding offers increased strength at all critical points.

Ipsen Industries, Inc., 721 S. Main Street, Rockford, Illinois.

Slug Heating Furnace

A small continuous furnace for the preheating of non-ferrous billets and slugs suitable for delivering to a press has been developed by Royce Electric Furnaces, Ltd., and has accommodation for three rows of billets, which may be up to 1 in. diameter and nominally 1 in. long. It provides temperatures up to 900°C. and has a total



output of 50 lb./hr., equivalent to 240 billets per hour.

The three rows of billets are pushed by a synchronous pusher gear which incorporates eccentric cams to give individual consecutive pushing to each tube, so that hot billets are discharged in rapid succession, one at a time, from each tube. A variable speed gear is incorporated in the pusher to provide adjustment to the heating time. Loading magazines are provided on the entrance end so that the furnace can work for considerable periods without the necessity of an operator. Fully automatic temperature control gear is provided, incorporating an electronic controller operating in conjunction with the necessary switchgear. For reduced outputs the furnace can operate with one or two rows of billets so that output could be varied from 80 to 240 billets per hour. To cover the reduced consumption a static indoor type transformer is provided with reduced tappings.

The furnace as illustrated and described is a typical unit, but the company specialises in the design of equipment of this nature to suit individual requirements.

Royce Electric Furnaces, Ltd., Albert Drive, Sheerwater, Woking, Surrey.

Laboratory Solenoid Control Valve

To be used in flow systems as an on/off control where the maximum flow rate is 525 ml./min. at 60 cm. head of water, the Grundy solenoid valve, manufactured by Griffin & George, Ltd., is a cylindrical glass plunger, actuated by a concentric solenoid from a mains control unit. The glass valve has an overall length of 110 mm. and is cylindrical, being 70 mm. long by 16 mm. in diameter, with rifled extensions to accommodate 5 mm. diameter tubing.

The cylinder contains a metal-cored glass plunger with a ground glass plug at one end which sits into the ground surface at the constricted outlet of the valve. The glass valve is mounted through the solenoid which is housed in a metal casting, 90 mm. in diameter, 57 mm. long, with an integral bosshead to accommodate rods of up to $\frac{1}{2}$ in. in diameter.

The control unit, housed in a sheet metal case $6\frac{3}{4}$ in. wide by 9 in. in depth, is a step-down mains transformer tapped at 12 V. with three circuits for controlling simultaneously (up to) three solenoids for operation on 200/250 V. cycles. The case is fitted with a white inclined front panel carrying a push-button on/off switch with an indicating light for each solenoid, a mains on/off switch, and a pilot light. The control panel and solenoid are housed in a synthetic hammer enamel finished case.

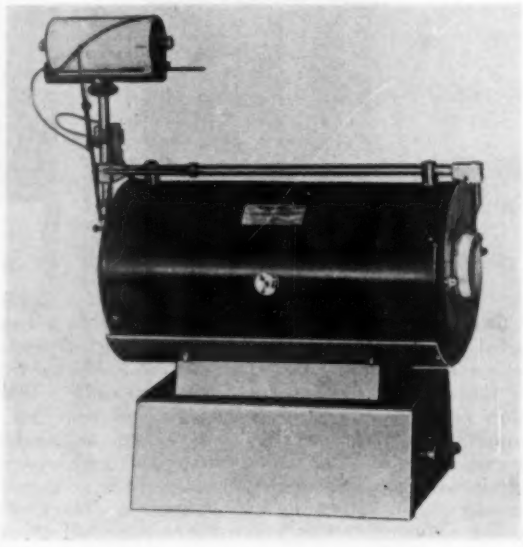
Griffin & George, Ltd., Ealing Road, Alperton, Wembley, Middlesex.

High-Precision Laboratory Furnaces

A RANGE of precision laboratory furnaces with exceptionally high stability of temperature (± 0·25° C.), an interchangeable drum control for thermal cycling, and facilities for heat loss compensation at the ends of the tube, have just been introduced by Shandon Scientific Co., Ltd. In the standard range there are three models for maximum temperatures of 1,050° C. with tube sizes respectively of 35 mm. I.D. × 290 mm. length (for operation on 115 V. A.C.), 60 mm. × 450 mm. (220 V. A.C.) and 75 mm. × 700 mm. (220 V. A.C.); and two models for maximum temperatures of 1,250° C. with tube sizes of 35 mm. × 290 mm. (115 V. A.C.) and 60 mm. × 450 mm. (220 V. A.C.). Two special models for maximum temperatures of 1,500° C. are also available, with tube sizes of 16 mm. × 250 mm. (115 V. A.C.) and 35 mm. × 400 mm. (220 V. A.C.).

The standard models may be controlled either by a thermostatic regulator or a chronograph drum control for thermal cycling, these temperature-control arrangements being interchangeable by the user. The thermostatic regulator, which enables the furnace temperature to be controlled within ± 0·25° C. at any desired level below the maximum, consists of a graduated scale and a pointer operated by a dilatable wire running through the furnace body. The scale is fitted with a stop which may be set to any desired temperature. When the pointer reaches the stop, the current is automatically cut off from the windings via the 8 V. relay. The temperature is set initially with the aid of a thermocouple.

The chronograph drum control for thermal cycling is clockwork-operated as standard but an electrically-



driven version is available as an alternative. The drum carries a temperature chart on which the desired thermal cycling programme is marked out by a strip of thick cardboard. In operation, the drum revolves at a set speed (the gearing arrangements provide two speeds), and, as the furnace heats up, a specially-designed contact on an arm connected to the dilatable wire moves across the drum. When it meets the cardboard, the relay operates and the current is cut off. In this way the contact follows closely the edge of the cardboard strip, alternately making and breaking the circuit to the windings, and thus holding the temperature to the planned programme.

The three separate windings are mounted side by side along the tube and may be controlled individually by shunt rheostats, thus enabling the temperature to be varied along the tube for special work or to compensate for the extra heat loss at the tube ends inherent in this type of furnace. All models may be mounted vertically or horizontally—in the latter case three different bases being available—and all models may be fitted with a water jacket, e.g. for use in a glove box.

The two special 1,500° C. models are developed from the standard types: they are available only with a chronograph drum control, which is not interchangeable with a thermostatic regulator, and incorporates special windings of platinum-rhodium wire. Like the standard models, they may be mounted either vertically or horizontally on any of the three available bases.

Shandon Scientific Co., Ltd., 6 Cromwell Place, London, S.W.7.

High Temperature Refractory Mortar

A NEW all-purpose bonding and surfacing mortar—Amberset—designed to prolong the life of refractory brickwork, and for use at temperatures up to 1,650° C., has been developed by the Amber Chemical Co., Ltd.

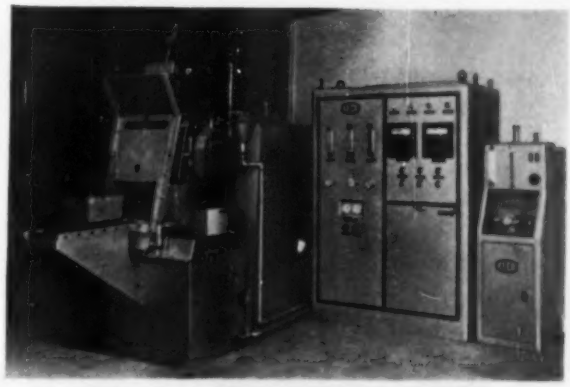
Amberset is an air-setting mortar which, it is claimed, satisfies the requirements of super-duty class refractoriness, and at the same time provides a bond stronger than the brick itself. Its resistance to thermal shock and good expansile characteristics enable the joint to withstand stresses due to thermal expansion and contraction. The very fine particle size of Amberset makes possible the use of extremely thin joints; this, in conjunction with the high bond strength, is an important factor in prolonging the life of refractories. Because of its smooth workability, Amberset can be readily applied as an impervious surface coating, thus further increasing the durability of the refractory.

Amberset is suitable for all types of industrial and marine boilers, heat treatment furnaces, kilns, water gas producing plants, and similar applications.

Amber Chemical Co., Ltd., 11a Albemarle Street, London, W.1.

Small Closed-Quench Furnace

A NEW junior size furnace has been introduced by the Electric Resistance Furnace Co., Ltd., to provide closed-quenching facilities for processing small quantities of work economically. Designed for gas carburising, carbonitriding and carbon restoration, the furnace incorporates a horizontal heating chamber, a purging chamber and an oil quench tank, and is fitted at the front with a roller conveyor, charging table. The work, in baskets, is moved into the furnace through an outer door fitted



with a gas screen to prevent the ingress of air. Inside the purging chamber the work is supported on a single-deck charge elevator subsequently used to lower the work into the oil quench. The charge is moved into the heating chamber with a push rod inserted through a hole in the outer door. The door to the heating chamber, the outer door and the charge elevator are all air operated with control levers mounted on the right hand side of the furnace.

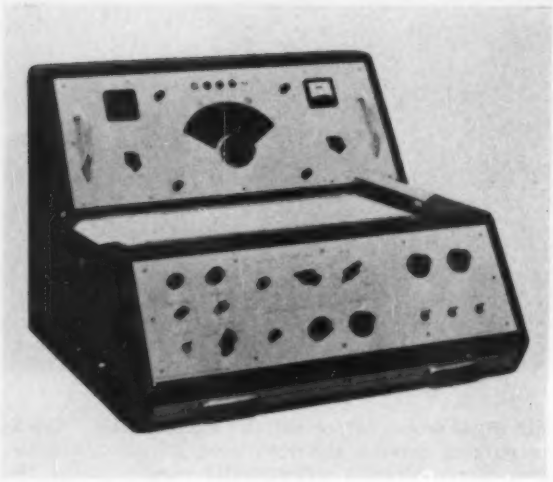
The heating chamber is fitted with radiant tube elements which are arranged for direct connection to a standard three-phase supply. These elements are rated at 15 kW., they are arranged in a single control zone and provide furnace temperatures up to 950° C. The atmosphere within the chamber is circulated by a fan driven by a water-cooled electric motor mounted on the top of the furnace. The oil quench tank is fitted with an oil cooler and a motor-driven oil agitator. The furnace accommodates work baskets 14 in. long by 8 in. wide by 8 in. high.

Electric Resistance Furnace Co., Ltd., Netherby, Queen's Road, Weybridge, Surrey.

Polarograph

THE Tinsley polarograph mark 200 manufactured by Evershed and Vignoles, Ltd., is an accurate and sensitive analytical tool capable of trace determination of materials in solution to better than 0·02 p.p.m. The classical D.C. circuit employed permits its operation from any type of electrode system, i.e. D.M.E., vibrating and rotating solid electrodes, or pool electrodes, etc., and the electrode may be positive or negative with respect to the reference electrode.

The polarograph mark 200 embodies a newly designed galvanometer transistor D.C. amplifier which uses two parallel feed-back circuits to adjust sensitivity in one feed-back loop and speed of response in the other. The recorder on which the final polarograms appear presents the trace on a horizontal table on which the operator may write the relevant experimental data most conveniently. The indicators for voltage and sensitivity are arranged at eye level and can be scanned at a glance, whilst the controls which are kept at the same setting throughout a series of experiments are arranged below the recorder table. The potentiometric recorder itself has an effective chart width of 200 mm. allied to a response time of 1 second and embodies its own integral amplifier: two chart speeds are provided. The overall



sensitivity of the polarograph covers from 0·02—100 μA. for full scale deflection.

A particularly interesting new feature is the provision of a peak reading unit (patent applied for) which eliminates capacity current noise from the normal D.M.E., and thus permits the chemist to obtain virtually undamped polarograms at all sensitivities without loss of resolution on both direct and derivative polarograms. Conventional damped polarograms may also be recorded (derivative type damping is used), and little or no zero shift will occur with either direct or derivative polarography. The potentiometer covers a voltage span from +0·5—3 and reverse with five scanning speeds for increased resolution.

The new polarograph is housed in a metal case, finished to very high standards, and makes use throughout of transistorised circuitry and printed circuits arranged in plug-in units to facilitate servicing and maintenance. The potentiometric recorder may also be used as a recording microammeter over its working range, without modification as suitable switching is provided.

Evershed & Vignoles, Ltd., Acton Lane, London, W.4.

Arc-Welding Electrode

A NEW arc-welding electrode, known as Opal 3½ Ni, has been developed by Cooper & Turner, Ltd., for the welding of low carbon 3½% nickel and similar steels where good Charpy impact values are required at sub-zero temperatures.

This new electrode is designated E.616 on the B.S.1719 coding or E.8016-C2 on the A.W.S.-A.S.T.M. scale. The basic coating employed gives a clean weld metal, free from minute inclusions of slag and gases, in conjunction with easy, fast deposition characteristics in all welding positions. Particular features are the stability of the arc and the ease of slag control, which enable D.C. and A.C. supplies down to 70 volts open circuit to be used. The mechanical properties obtained include a Charpy impact value of 15/20 ft./lb. at —100° C., a yield point of 27/31 tons/sq. in., and an ultimate tensile strength 34/40 tons/sq. in. The carbon content is 0·5—0·8%, with silicon 0·25—0·50%. The manganese content lies between 0·4 and 0·8% and both sulphur and phosphorus are below 0·03% each. The nickel content is in the range 3·25—3·75%.

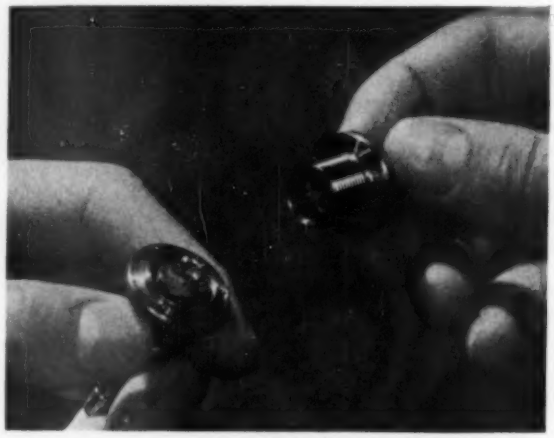
The electrode is produced in a range of five sizes from 12 gauge to 4 gauge. The current values range from 90 A. average and 110 A. maximum at 12 gauge to 260 A. average and 320 A. maximum at 4 gauge, the deposition time per foot of electrode at maximum current being 51 seconds at 12 gauge and 62 seconds at 4 gauge. The weight of metal deposited per cwt. of electrode rises from 64 lb. at 12 gauge to 78 lb. at 4 gauge, whilst the weight of electrodes required to deposit 100 ft. of fillet weld in the downhand position is 7·5 lb. with a leg length of ¼ in. and 86·5 lb. with a leg length of ½ in.

Cooper & Turner, Ltd., Vulcan Works, Vulcan Road, Sheffield, 9.

Compact Thermocouple Connector

WEST INSTRUMENT, LTD., are producing to an oil- and water-tight design a compact cheap thermocouple plug which, it is claimed, eliminates the errors often introduced at the union with extension wiring. It is suitable for terminating thermocouples so that a quick and easy connection can be made to extension leadwire, so that thermocouples can be replaced without disturbing what may be a complicated and expensive run of leadwire. It also eliminates the need for terminal strips and other types of connectors which could cause errors because of vibration, dirt and other factors.

The pins and sockets of the West connector are made of thermocouple materials to prevent spurious e.m.f.'s being produced as a result of temperature gradients over the plug and socket. The connectors are also polarised to prevent faulty connections. The housing is made of Monel and the dimensions are approximately ⅞ in. diameter × 1½ in. long.



This junction has been tested and bought in large quantities by the Admiralty for use with the gas and steam turbine installations on the new Tribal class of vessel. It is also suitable for the complete range of thermocouple types—including mineral insulated thermocouples—in the metallurgical, nuclear and general engineering fields.

West Instrument, Ltd., Regent Street, Brighton, Sussex.

CURRENT LITERATURE

Book Notices

WERKSTOFFE FÜR ELEKTRISCHE KONTAKTE
(Materials for Electrical Contacts)

By A. Keil. 347 pp. Springer-Verlag, Berlin/Göttingen/Heidelberg. (In German). DM48.

Here is a book which is positively bursting with useful information. It opens with a discussion on fundamental physical matters such as phenomena in the contacting of current carrying parts, permanent contacts, interrupting contacts, switching contacts—non-current or under load, electrical discharge in gases, application of arc theory and sliding contacts. Then follows a detailed discussion of metallurgical aspects covering ordinary contact metals and alloys (aluminium, copper, mercury, nickel, noble and platinum metals and their various alloys) as well as pure metals obtained by sintering (rhenium, tungsten, molybdenum) and sintered alloys (copper-tungsten, silver-metal oxides, silver with high melting point metals or carbides, silver-graphite).

The next section covers various materials problems arising including chemical reactions in contacts at rest, surface reactions in contacts under load, effects in the arc gap, migration of materials, conditions at contact tips and electrochemical effects in sliding contacts. Finally consideration is given to the practical choice and fabrication of materials: production of various types of metal and alloy contacts, design, checking of defects, and joining.

There are various useful tables and diagrams covering melting and boiling points, vapour pressures and other physical properties of metals, ionisation potentials and work functions and the like; and concise notes on the properties and applications of numerous contact metals and alloys, indicating those applicable for various purposes, with similar treatment of welding and brazing filler metals. References are provided in footnotes throughout the text, and what is more they are up to date! Possessors of this book will wear it out with constant use.

ALUMINIUM CORRUGATED AND TROUGHED SHEETING

56 pp., numerous diagrams. Applications Brochure 14, London, 1960. The Aluminium Development Association, 33 Grosvenor Street, London, W.1. 10s. 6d.

This is the latest in the A.D.A. series of illustrated brochures showing examples of the usage of aluminium in a particular field coupled with a considerable amount of technical information. The text and data have been brought together with the architect, builder, engineer and surveyor particularly in mind, and the book describes aluminium corrugated and troughed roofing sheets by reference to the appropriate British Standards for this form of material which has given long service in industry and agriculture.

The book opens with a brief statement of the advantages of aluminium in this field and then establishes clearly the various profiles—with reference to the appropriate British Standards—before describing the weight, strength, thermal and other characteristics of the material for this purpose. There is a brief section dealing with components and accessories, and the choice of sheet profile for a particular purpose is covered by tables of section properties and maximum recommended loadings. Though the book does not purport to be a text book on design, the essential points concerning design loading are established together with other considerations such as roof pitch and laps. The concluding sections of the book deal with installation practice and, very briefly, with the few points on site handling and storing that are of importance for aluminium. Appendices deal with the composition and minimum mechanical properties of the most commonly used alloy for roofing and cladding, with the net width covered by sheets of given dimensions, and with the various aspects of thermal insulation using aluminium.

Finally, the section that may well be of greatest interest to the architect and the engineer is the set of drawings, comprising the twelve centre pages of the book and which give general details, fixing and laying details, and arrangements, such as can easily be applied to particular problems. These drawings can readily be detached from the book, if required, but the Association has in preparation sets of them which, in due course, will be available separately from the book.

PROTECTIVE CLOTHING AGAINST FLAME AND HEAT

Fire Research Special Report No. 3 published for D.S.I.R. and Fire Offices Committee Joint Fire Research Organisation by H.M.S.O. 3s., by post 3s. 4d. (U.S.A. 54 cents).

Recommendations on the design and use of protective clothing for aircraft crash workers are discussed in this Fire Research special report. These are based on laboratory tests devised and carried out by the Joint Fire Research Organisation to assess the protection afforded against flames and heat by many types of clothing, and are applicable, in addition, to protective clothing for workers in industries involving high temperature processes. The report analyses conditions of air temperature and radiant heat which firemen and some industrial workers may encounter. It continues by discussing in simple terms the effect of heat on the human body as well as the limits of tolerance and, finally, explains the ways in which suitable protective clothing can give protection against differing conditions of air temperature and radiant heat. Thus, for example, the intensity of thermal radiation encountered by a rescue worker at an aircraft crash fire may be about 0·5 calories per square centimetre per second. Radiation at this intensity falling on unexposed skin could cause unbearable pain in under two seconds, but clothing with a suitable reflecting outer surface could afford protection for a matter of minutes without undue discomfort. Contact with flames, however, would rapidly destroy the reflecting power of the surface, and under these conditions it is necessary that the insulation of the garment and its ability to store heat should be sufficient to give adequate protection. There are short notes as well on special requirements for protection for the head, hands and feet, and methods of obtaining protection for long periods by artificially cooling the clothing externally.

Trade Publications

We have received from C. F. Casella & Co., Ltd., a copy of a brochure published recently to celebrate their 150th anniversary. The brochure incorporates a brief history of the company, along with a section illustrating selected instruments in the current range. These include meteorological instruments, airborne dust and bacteria samplers, pressure measuring instruments, dewpoint meters, etc.

Griffin & George, Ltd., the laboratory furnishers, have now completed distribution of their current price list of volumetric and lampblown glassware, and all those customers in educational, industrial and research laboratories who are on the group's mailing list should have received their copy. The catalogue (P.2121) comprises some sixty pages, profusely illustrated with a wide range of Griffin and E-Mil glassware, including burettes, flasks, pipettes, butyrometers, soxhlet extractors and viscometers. Copies are freely available from any of the group's regional offices.

Investigations on the properties of welded specimens of Nimonic alloys in sheet form are summarised in a new publication. Graphs show results of determination of maximum stress, creep values and elongation of the welded specimens at various temperatures, and also show the effect of alternative heat treatments applied to Nimonic 90 heat-resisting alloy. Data are included on a new Nimonic alloy produced in sheet form (temporarily designated "Nimonic EPE7"). The publication is obtainable free on request from Publicity Department, Henry Wiggin & Co., Ltd., Thames House, Millbank, London, S.W.1.

The Engineering Group of The General Electric Co., Ltd., has recently produced three new publications, dealing with roller hearth furnaces, high temperature furnaces with hydrogen atmosphere, and induction heating furnaces. G.E.C. roller hearth furnaces (Publication E.75) are available in a variety of forms which meet every possible requirement for continuous-flow heat treatment processes. Suitable for heating in air or in a controlled atmosphere, ratings and dimensions can be made to suit individual requirements. Furnaces over 400 ft. long and with ratings of approximately 2,000 kW. have been manufactured by the company. For heat treatment up to 2,500°C., G.E.C. makes use of molybdenum and tungsten heating elements in its range of high temperature furnaces. Publication E.78 states that such furnaces are being used in the powder metallurgy industry where temperatures up to 1,700C°. are required. Hydrogen is used to prevent oxidation of the elements at these elevated temperatures. Both batch and continuous molybdenum furnaces for operation up to 1,700°C. are available. The use of tungsten elements is, however confined to small laboratory furnaces working between 1,700°C. and 2,500°C. The publication covering induction heating furnaces, E.67, describes mains-, medium-, and dual-frequency induction furnaces supplied by G.E.C. for heating and reheating of ferrous and non-ferrous alloys. Typical applications include the rolling of ingots, slabs, blooms and billets; extrusion of billets; forging and hot pressing of billets and slugs; and stress relieving of bars. Mains frequency (50 c./s.) is used in furnaces suitable for the through-heating of magnetic steels of 6 in. diameter and above. Medium frequencies (100–10,000 c./s.) are necessary for furnaces to be used for through-heating and hardening of steels from ½ in. to 6 in. diameter.

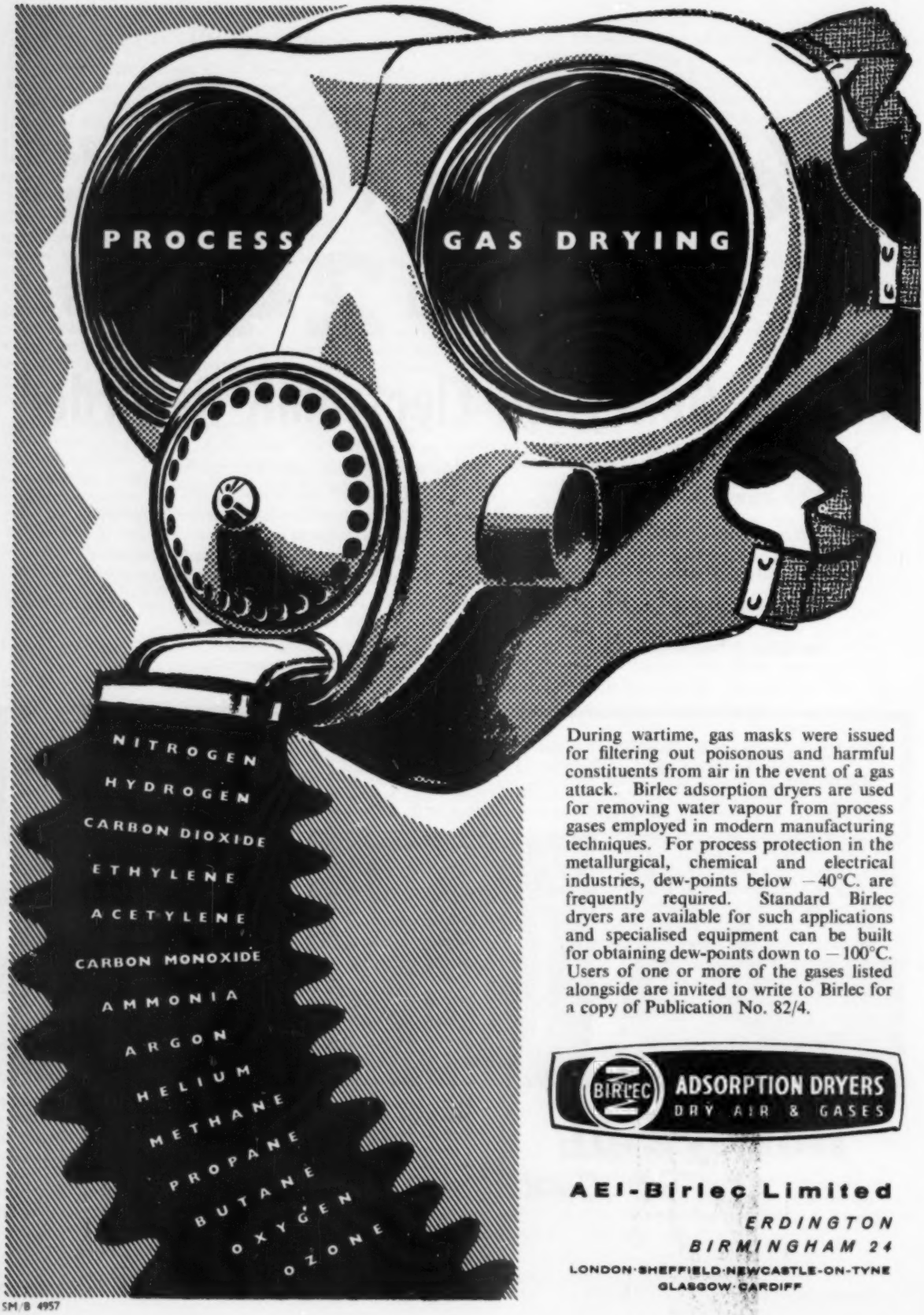
A new publication by Henry Wiggin & Co., Ltd., is designed for the welder of dissimilar metals. For many years it was the general rule that the filler metal should match the higher alloy of the metals being joined, and although this proves satisfactory for some combinations, there are many instances where undesirable deposits have resulted from the filler metal being diluted with the lower alloy base metal. These difficulties are not insurmountable, and the publication explains with tables and illustrations how Inco-Weld "A" electrode and filler wire have been specially developed and are the first welding materials ever to be specifically designed for joining dissimilar metals. The publication is obtainable free on request from Publicity Department, Henry Wiggin & Co., Ltd., Thames House, Millbank, London, S.W.1.

There is a light-hearted yet sound approach to a technical subject in a new 56-page booklet "Weldability" issued by English Electric. Designed to go in the welder's pocket and liberally illustrated with cartoons and simple diagrams, the booklet is full of tips for better welding' Its aim is to talk to the man on the job, the welder, a craftsman who often has very definite ideas on the electrodes he wants to use. The first half of this easy-to-read booklet deals with the principles of good welding, detailing the necessary equipment and types of welds, explaining terms, symbols and British Standards. The second part covers English Electric arc welding electrodes and equipment. The purpose of each is clearly explained and there is a helpful section at the end on welding troubles, their cause and cure. The booklet is produced by the Welding Division of English Electric, East Lancashire Road, Liverpool, 10.

The abstracts contained in the November issue of *The Nickel Bulletin* provide, in the diversity of their subject matter, an apt illustration of the wide range of industries and applications in which nickel, and nickel-containing materials, play an important role. The literature referred to in the section concerned with nickel-containing heat- and corrosion-resisting materials covers, *inter alia*, the development of high-temperature brazing alloys, the atmospheric corrosion-resistance of architectural alloys and steels, the mechanical properties and welding characteristics of various stainless steels and nickel-base alloys, and the resistance of such materials to specific corrosive media. Items in the section on nickel draw attention to work on the extraction, refining, determination and analysis of the metal, while papers on the electrodeposition of nickel alloys and the mechanism of levelling in nickel-plating solutions are among those referred to in the electrodeposition section. Items of particular interest in the other sections of the issue cover fusion-line cracking in welded cupro-nickels, graphitisation in nickel-containing cast irons, and the properties of structural steels suitable for use in such low-temperature applications as the containment of liquefied gases.

Book Received

"A History of Platinum : From the Earliest Times to the Eighteen Eighties." By D. McDonald. 250 pp. inc. index ; numerous illustrations. London 1960. Johnson, Matthey and Co., Ltd. 35s. net.



SM/B 4957

During wartime, gas masks were issued for filtering out poisonous and harmful constituents from air in the event of a gas attack. Birlec adsorption dryers are used for removing water vapour from process gases employed in modern manufacturing techniques. For process protection in the metallurgical, chemical and electrical industries, dew-points below −40°C. are frequently required. Standard Birlec dryers are available for such applications and specialised equipment can be built for obtaining dew-points down to −100°C. Users of one or more of the gases listed alongside are invited to write to Birlec for a copy of Publication No. 82/4.

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INSTRUMENTS AND MATERIALS
JANUARY, 1961 Vol. LXIII, No. 375

New Spectroscopies in Metallurgical Research

Experience with an X-Ray Fluorescence Spectrometer and a Solids Mass Spectrometer

By K. M. Bills

The Mond Nickel Co. Ltd., Development and Research Department, Birmingham.

Recognition of the limitations of optical emission spectroscopy in respect of accuracy and sensitivity led to a study of potentially useful supplementary techniques. None appeared to meet the demands for both accuracy and sensitivity, but it appeared that X-ray fluorescence spectroscopy could provide the former and mass spectroscopy the latter. A practical assessment of the performance of the Solartron XZ. 736 double-beam automatic X-ray fluorescence spectrometer and the Metropolitan-Vickers (now AEI) M.S. 7 solids mass spectrometer on the basis of several months' continuous operation is presented here.

DURING recent years metallurgical research has made increasingly exacting demands on the analyst, both in the closer specification limits within which alloys must be produced and in reduced tolerances towards deleterious trace elements. Optical emission spectroscopy has continued to make a major contribution to analysis, and the usefulness of this technique has increased as direct-reading methods have become commonplace and as vacuum spectroscopy has been successfully applied to some of the problems involved in the determination of non-metallic elements. Nevertheless, the accuracy of the technique is restricted by sampling errors and, to a lesser extent, by instability in the light source. Sensitivity is limited by the spectrum line/background ratio which is influenced by various factors, among which are the physical properties of the impurity sought, relative to those of the matrix. This line-to-background ratio may be favourably influenced by various devices, but in general the limit of detection for a direct technique is of the order of 1—100 p.p.m., depending upon the particular element and matrix. Sensitivity may be substantially improved by chemical concentration of the required impurities, and whilst this is excellent for routine control purposes, it necessarily presupposes knowledge of the identity of the required elements, and is therefore of little value for the general survey work often called for in metallurgical research.

The need to supplement emission spectroscopy in order to secure greater accuracy and sensitivity resulted in a detailed survey being made of potentially useful techniques, the criteria being, for accuracy, $\pm 0{\cdot}25\%$ of content, and, for sensitivity, a limit of detection of 1 part in $10.^6$ Details of this survey have been reported elsewhere;[1] the general conclusion was that no single technique offered both the required accuracy and sensitivity. Nevertheless, it appeared that both demands could be met separately—accuracy could be provided by X-ray fluorescence spectroscopy, whilst adequate sensitivity could be achieved by mass spectroscopy. Practical proof was provided by tests carried out on a General Electric X-ray spectrometer at the Mond Nickel Co.'s Birmingham Research Laboratory, and on a prototype mass spectrometer constructed in Metropolitan-Vickers' Research Department in Manchester. Following the success of these trials, a Solartron XZ. 736 double-beam X-ray fluorescence spectrometer and a Metropolitan-Vickers M.S. 7 solids mass spectrometer were installed during 1959 in the Analysis Section of the Birmingham Research Laboratory, and have now been in continuous operation for several months. A practical assessment of the performance of these two new and important instruments can now be made.

Double-Beam Automatic X-Ray Fluorescence Spectrometer

The general principles of X-ray fluorescence spectroscopy have long been established and need only be briefly summarised here. The sample is irradiated by a beam of X-rays of energy sufficient to excite the characteristic radiations of its component elements by fluorescence. This heterogeneous radiation, emerging from the sample surface at all angles, may, after suitable collimation, be diffracted into its component wavelengths by various crystalline substances. Electrical detectors are available whereby the intensity of the characteristic X-ray spectrum lines may be related to content. The two essentially novel features of the Solartron XZ. 736 double-beam automatic X-ray fluorescence spectrometer are that it is a true double-beam instrument (in fact, twin spectrometer), so that intensity variations in the primary X-ray source are largely nullified and, secondly, that the spectrometer is automatically set, by means of servo-mechanisms, to a predetermined sequence of spectrum lines. A schematic representation of the

[1] Proc. 11th Chemists' Conference. B.I.S.R.A. Special Publication, pp. 35–42.

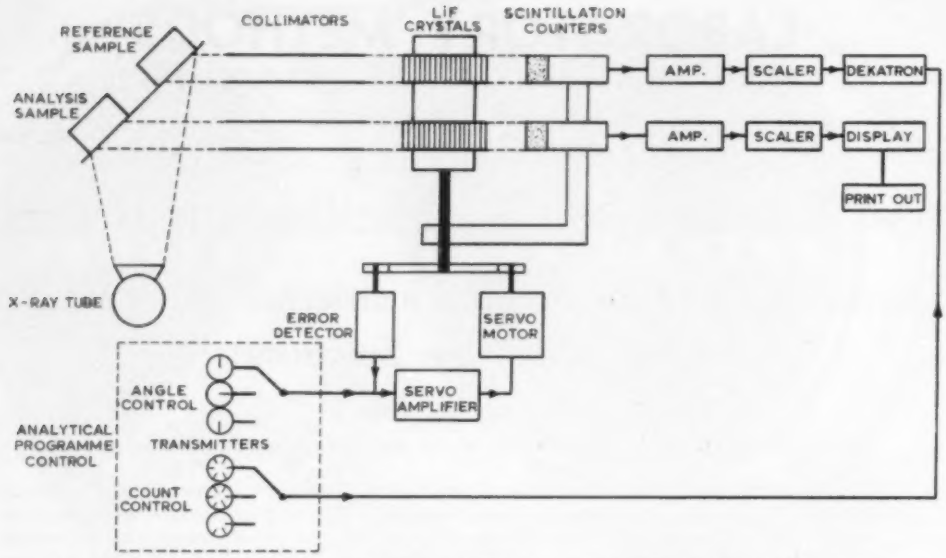


Fig. 1.—Schematic diagram of the Solartron double-beam X-ray fluorescence spectrometer.

spectrometer is shown in Fig. 1. The three basic components of this spectrometer are :—

(1) The X-ray source,

(2) The spectrometer, and

(3) Intensity-measuring equipment.

A description of these three parts is given below.

The X-Ray Source

A vertically-mounted Matchlett OEG 60 tungsten-target X-ray tube is fed from a stabilised power source ; tube voltage and current are independently stabilised to within $\pm 0{\cdot}1\%$. In each case the " error " signal is derived from the secondary circuit, thus avoiding the defects of simple supply voltage stabilisation. The current and voltage may be varied stepwise, covering, respectively, the range 10, 20, 30, 40, 50 mA., and 20, 30, 40, 50 kV.

The Spectrometer

The "twin " form of the spectrometer will be appreciated from a consideration of Fig. 1. 1 in. $\times \frac{5}{8}$ in. rectangular areas of both analysis and references samples are irradiated in the water-cooled, fully-shielded sample enclosure. Two sample holders with protective cups on a sliding mechanism are provided for each channel, so that samples may be loaded in advance. Safety devices are incorporated to protect the operator from radiation hazards. The fluorescent radiation from the samples is made into a parallel beam by the collimators which consist of 7 in. long molybdenum foils, with 10-thou. spacing between adjacent foils. Since the analysis sample is much nearer the X-ray tube window, an adjustable shutter is provided to reduce the X-ray intensity and so balance the two channels.

After leaving the collimators, the beam is diffracted by LiF crystals and detected by thallium-activated sodium iodide scintillation counters. The crystal holder and the arm bearing the scintillation counters are coupled by a 2 : 1 gearing system to fulfil the requirements for Bragg diffraction.

The analytical programme of the spectrometer is determined by a uniselector switch, which connects each transmitter in turn to a similar receiver unit driven off the crystal-holder and detector-arm gearing. If the rotors of the transmitter and receiver are not at exactly similar angles a voltage is generated which is proportional to the angular difference. After suitable amplification the error signal drives the servo motor, and thus the spectrometer, until the rotors of the transmitter and receiver are coincident, producing zero-error signal. The transmitter can therefore be calibrated in terms of θ, the Bragg angle, and the spectrometer follows the angular settings with great precision—tests have shown a reproducibility of better than $\pm 0{\cdot}002^\circ$ of θ. The Laboratory's instrument is equipped with twelve transmitters ; thus a programme of twelve angles, elements or spectrum lines may be accommodated and changes may be made to the analytical programme in a matter of seconds. The spectrometer is illustrated in Fig. 2.

Intensity Measurement

The scintillation counter has two basic elements—a flat single crystal of sodium iodide activated with 1% of thallium, and an " end-on " photomultiplier tube. X-ray quanta excite fluorescent centres in the crystal and the visible photons produced excite current pulses in the photomultiplier. The number of these pulses is a measure of the intensity of the X-ray beam and their amplitude is proportional to the quantum energy (or, effectively, wavelength). These pulses, from both analysis and reference counters, are amplified by twin head-amplifiers of lower output impedance and are fed to the main measuring console. Here the pulses are further amplified by linear amplifiers and then passed to single-channel pulse-height analysers. These are set to pass only those pulses exceeding a pre-determined

amplitude, thus discriminating against unwanted spectrum background. Since the precise setting of this base level is very critical, both pulse-height analysers share a common reference voltage, which may be adjusted to secure optimum performance. As this optimum varies from wavelength to wavelength, a compromise value has to be determined : this is largely influenced by the need to obtain good response to the softer X-rays where the pulse amplitudes are comparatively low. After amplification and base-level discrimination, pulses of a common amplitude are obtained in order to secure satisfactory operation of the five-digit counters.

Counting on any particular line is automatically terminated at a pre-determined number of counts in the reference channel, individual control for this purpose being provided with each transmitter. Since for a given sample the counting accuracy is dependent upon the number of counts accumulated, this control may be regarded as an accuracy control, as follows :—

Setting, Total Count	*Coefficient of Variation* (%)
10^3	4·2
3×10^3	2·5
10^4	1·4
3×10^4	0·8
10^5	0·42
3×10^5	0·25
10^6	0·14

In addition, a " SELECT " position is provided, whereby any special value for the reference count may be determined.

When a particular reference count has been completed, the analysis counters display the total accumulated count for the " unknown " sample which, by virtue of this method of external standard control, is automatically corrected for any residual fluctuations in the primary X-ray beam. As well as the visual display by the Dekatron counters, the analysis count is printed out on an electrically-operated adding machine, which also prints out the number of the particular transmitter involved.

If a count selector switch is set to its " OFF " position the particular transmitter is by-passed ; thus, only the desired number of angles or elements is measured. In order to obtain a fully automatic sequence in normal operation, the last transmitter (No. 12) is always switched on and set to Ni Kα (24·32° of θ). Thus the spectrometer will automatically come to rest on the lowest-number transmitter switched on, and on depression of the start button it proceeds automatically to measure sequentially the predetermined programme of angles. When the last transmitter (No. 12) is selected a warning light is illuminated, reminding the operator that the analysis is nearly complete and that the next sample should be loaded into the idle sample holder. After completion of the count on No. 12 transmitter the spectrometer automatically re-sets itself to the lowest-number transmitter and stops. The new sample is then slid into position over the X-ray beam, the start button is depressed and the cycle is repeated.

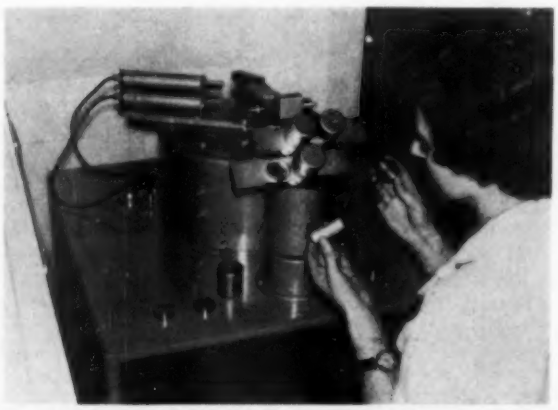


Fig. 2.—Solartron double-beam X-ray fluorescence spectrometer.

Fig. 3.—Control and measuring console of Solartron instrument.

Provision is made for shorting-out the start button so that the spectrometer will automatically repeat the analytical programme on a given sample until a " RESET " button is depressed. By the use of this facility reproducibility tests may be carried out without any operator in attendance ; all that is required is the initial setting up of the analytical programme, depression of the start button, and subsequent switch-off when sufficient data have been accumulated. Additional facilities include a crystal oscillator for single-channel working against time and a continuous scan with chart recorder. The control and measuring console is shown in Fig. 3.

Performance

The most important feature of such a complex analytical instrument is its stability. Provided the short-term stability is good, calibration graphs may be drawn up for each batch of work and adequate accuracy is achieved. If all the work is of a similar nature, requiring measurements on only a single group of standards, such a procedure, carried out two or three times a day, is not unduly onerous. However, since the Laboratory's analytical interests cover copper- and iron-base materials as well as a wide range of nickel alloys, such frequent calibration is impracticable. Considerable attention has therefore been paid to long-term stability.

When the instrument was first installed tests were

TABLE I.—STABILITY TESTS* ON MONEL TEST SAMPLE
(Transmitter 11 : Cu Kα ; Transmitter 12 : Ni Kα.)

Transmitter	Total Count		
	First Check	Second Check	Third Check
11	289·500	289·210	287·920
12	668·410	668·230	671·050
11	287·360	291·250	289·580
12	671·220	669·250	670·020
11	290·730	290·090	290·830
12	671·880	668·670	673·000
11	288·840	289·660	288·940
12	669·550	669·630	673·770
11	291·160	290·360	288·780
12	673·350	669·180	671·890
11	290·300	290·790	288·860
12	674·130	669·470	670·390
11	287·91 .	290·510	289·270
12	671·3/0	666·940	673·120
11	290·470	291·280	290·250
12	673·160	667·870	670·820
11	290·450	289·770	290·000
12	673·260	667·980	673·740
11	290·870	289·620	290·650
12	669·660	669·520	671·490
Mean Copper Count	289·810	290·250	289·510
Range (%)	1·5	0·71	1·0
Mean Nickel Count	671·600	668·670	671·930
Range (%)	0·85	0·42	0·55

*For three consecutive days.

carried out to determine the period required to stabilise from switch-on, taking measurements of copper Kα line from a sample of Monel (70/30 nickel-copper) for a total count of 10,[6] where the theoretical counting accuracy (coefficient of variation) should be 0·14%. Taking twice this value (0·3%) to cover nine out of ten results, so that stability could be judged simply by inspection, it was found that in spite of the use of the double-beam principle 2-2½ hours were required before acceptable results were obtained. The "warm-up" pattern was always similar—first, three or four completely erratic results, produced over a period of about 10 minutes, followed by a slow drift (always in the same positive direction) until, 2 hours later, adequate stability was achieved. The calibration would then hold good for the rest of the day, but could not be used the day following.

It subsequently appeared that the greater part of the drift was due to changes in the X-ray tube filament (possibly a creep phenomenon) and, to a lesser extent, to changes in the measuring circuits. The "warm-up" period could be reduced to a few minutes' duration provided that the X-ray filament and measuring console were permanently switched on. This is now normal practice ; a regular check on stability is obtained by leaving the instrument set up each evening with a sample of Monel in both reference and analysis channels and transmitters 11 and 12 set to read the copper and nickel Kα lines respectively. The controls are set for repetitive operation ; the X-ray anode volts are switched on and the start button is depressed 30 minutes before normal working hours. The instrument is thus stabilised and a check on calibration is made before the day's work begins. The results of three such consecutive checks are shown in Table I.

$$\frac{\text{Total count}}{10{,}000} = \text{Element content \% (approx.)}$$

The results of reproducibility tests on copper in Monel

TABLE II.—REPRODUCTIBILITY TESTS ON MONEL TEST SAMPLE

	Run 1 (200 determinations)	Run 2 (200 determinations)
Mean Count	1,034,809	1,033,900
Standard Deviation	± 2,110	± 2,550
Copper (%)	28·15	28·12
Standard Deviation (%)	± 0·06	± 0·07
Coefficient of Variation (%)	± 0·21	± 0·25

at 10^6 counts, summarised in Table II, show that reproducibility is only slightly inferior to that expected from theoretical considerations.

For all practical purposes, the technique is non-destructive, but during these reproducibility tests, when samples were exposed to the X-ray beam for many hours, it was discovered that the slight discolouration of the sample surface was due largely to corrosion by nitrogen peroxide, produced photochemically in the sample chamber, rather than as a direct consequence of X-ray bombardment of the samples.

The sensitivity of the instrument varies considerably according to the element ; sensitivity relative to nickel for various pure metals is shown in Fig. 4. The fall-off towards the lighter elements is due to air absorption and reduced counter efficiency, while the reduced sensitivity for the harder elements is caused by a lower excitation efficiency and the smaller effective aperture of the spectrometer at high Bragg angles. In normal practice, in order that the counting times should not be too long (not exceeding 5 minutes and averaging 30 seconds), the contents analysed are restricted to those exceeding 0·2—0·5%, the latter content being the effective limit for titanium, the element of lowest atomic number which can be analysed with an air-path spectrometer.

Many varieties of materials are readily analysed—bronze ; cast iron ; low-and high-alloy steels ; nickel-copper ; nickel-iron and nickel-iron-cobalt controlled-expansion alloys ; and, most commonly, complex nickel-base alloys for high-temperature applications, containing major amounts of chromium, cobalt and molybdenum, tungsten, niobium, titanium and aluminium. Repro-

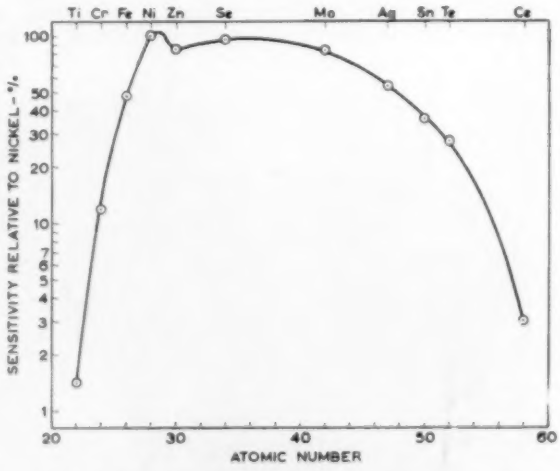


Fig. 4.—Relative sensitivity of various elements using the Solartron X-ray fluorescence spectrometer : Kα first order lines ; tungsten target ; 50 kV. ; LiF crystals.

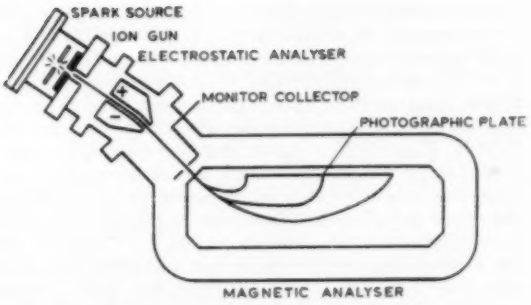


Fig. 5.—Schematic diagram of Metropolitan-Vickers M.S.7 solids mass spectrometer.

ducibility is excellent : accuracy is necessarily somewhat inferior, due to inter-element effects caused by absorption processes in the sample but, in general, provided appropriate standards are available, an accuracy approaching that of the best chemical methods may be obtained, in a fraction of the time.

X-ray fluorescence spectroscopy supplements emission techniques with precise analyses of the major alloying constituents. In the content range 0·2—5·0% the two techniques are in direct competition, with the advantage slightly to the X-ray method if direct-reading techniques are compared. Photographic-emission methods are at a definite disadvantage.

Solids Mass Spectrometer

Turning to trace-element analysis, which is of increasing importance to the metallurgical industry, the new technique of solids mass spectrometry offers an elegant solution to the difficult problem of the sub parts-per-million range of contents. As with X-ray fluorescence, the basic principles of mass spectroscopy have long been known, but practical exploitation has had to wait upon technological developments and on industrial demand. The fundamental principles are in themselves simple. Positive ions are produced from the sample by a spark discharge and are accelerated through an ion gun into an electrostatic analyser, from which a mono-kinetic beam emerges to be dispersed by a magnetic analyser according to the mass of the component ions. The mass spectrum is recorded on a photographic plate, the presence of a particular element is deduced from the appearance of a line or lines corresponding to a particular mass, and the content is related to the intensity of these lines.

A schematic diagram of the Metropolitan-Vickers M.S. 7 solids mass spectrometer is shown in Fig. 5. The instrument itself consists of two units—one containing the mass spectrometer with its associated vacuum systems and control circuits, the second housing the various stabilised power supplies. A view of the operating desk of the spectrometer is shown in Fig. 6.

From the electronic point of view the instrument is much simpler than the X-ray spectrometer, since it is a photographic recording instrument not intended for high-speed routine operation. It has, however, the complications of a critical high-vacuum system. Because of the greater simplicity of the spectrometer, the instrument may be more easily described by a consideration of the various stages of a mass-spectrographic analysis.

Fig. 6.—Metropolitan-Vickers M.S.7 solids mass spectrometer.

Preparation and Excitation of the Sample

Two sample electrodes are required, $\frac{1}{4}$ in. long and approximately $\frac{1}{16}$ in. diameter. Owing to the high sensitivity of the technique, preparation of the sample is the most critical stage in an analysis and the utmost care is necessary to avoid contamination. A sample blank is first roughed out, approximately $1\frac{1}{2}$ in. long and $\frac{1}{2}$ in. diameter. This is then machined into final form by the operator of the mass spectrograph, using a miniature lathe with a tungsten-carbide-tipped tool. The machined electrodes are stored in individual polythene vials until shortly before the analysis is to be begun. They are then degreased, pickled successively in aqua regia and hydrofluoric acid, and washed in de-ionised water. After drying they are transferred without delay to the source chamber of the mass spectrometer, access to which is provided by a glass plate and an " O " ring seal. The electrodes may be adjusted by external controls operating through metal bellows. A view of the source chamber is shown in Fig. 7.

The component elements of the sample are produced in the ionic form by passing a high-voltage spark between the sample electrodes. The spark unit consists of a trigger circuit controlling the operation of an R.F. oscillator and power amplifier, the output of which is applied to the electrodes through an H.F. step-up transformer. The output voltage is continuously variable up to 100 kV. Normally, the voltage used is the minimum which is required to secure stable operation of the spark in order to suppress formation of polyatomic ions, e.g. Ni_2^+, which may form between any of the isotopes of an element or between different elements, thus complicating the spectra and making interpretation difficult. An additional complication arising from the

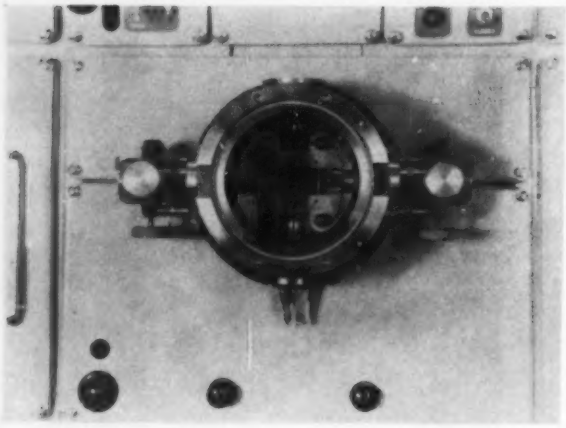


Fig. 7.—Source chamber of the solids mass spectrometer.

excitation process results from the formation of multiply-charged ions. Spectrum lines due to doubly-charged ions appear at exactly half the mass number of the singly-ionised isotopes, triply-ionised lines at one-third the mass, and so on. Fortunately, the intensity of the lines produced by the multiply-charged ions decreased by a factor of about four of five between successive stages of ionisation.

Production of the Mass Spectrum

The ions so produced are accelerated through an ion gun maintained at −20 kV. relative to the spark, and a narrow beam passes in the electrostatic analyser. This consists of two curved stainless-steel plates, $\frac{3}{4}$ in. apart maintained at a voltage between plates of 10% of the accelerating voltage, and stabilised to 1 part in 20,000. The purpose of the analyser is to eliminate the large energy spread in the ion beam produced by the spark source. On passing into the magnetic analyser the ions are brought to a focus at the photographic plate, as a series of lines, the horizontal position of which is a function solely of their mass, unaffected by their initial kinetic energy. The magnetic field in the main analyser is continuously variable from 2,000 to 16,000 gauss over a $\frac{1}{8}$ in. gap so that, effectively, the mass-spectrum range and dispersion may be varied to suit individual analytical problems. As in optical spectrographs, in order to maintain resolving power, the dispersing device must be extremely stable, and to this end the current through the electromagnet is stabilised to 1 part in 40,000. Under normal operating conditions, with an accelerating voltage of 20 kV. and a field strength of 15,500 gauss, ions of mass 6–250 (lithium to californium) are recorded in a single exposure. The photographic plates employed are 10 in. × 2 in. Ilford QII ; up to thirteen exposures may be made on a single plate and the spectrometer has a magazine capable of holding eight plates. Electrical detectors capable of measuring the minute ion beams resulting from trace contents in the 1–0·1 p.p.m. range have not yet been developed, but the monitor collector, situated between the electrostatic and magnetic analysers, measures the total ion-beam before dispersion, both as an instantaneous and as an integrated value. The latter is used to control the exposure period, a particularly important facility because the vacuum spark is maintained only with difficulty and requires more or less constant adjustment.

The ion-beam intensity range to be registered by the photographic emulsion is very great, and it is necessary for quantitative work that lines of both matrix and impurity elements should be recorded within its proper working range, in order that a ratio, or "internal standard," procedure may be employed. To this end, a series of graded exposures is made of each specimen, the number of exposures depending on whether visual or photometric methods of spectrum evaluation are employed.

Interpretation of Spectra

As in all comparative analytical techniques, the major problem in solids mass spectrometry is the provision of adequate standards. Indeed, in view of the sensitivity of the method and its ability to deal with virtually all elements, anything more than a relatively small number of check analyses by other analytical techniques will be impracticable. The technique has, however, a number of unique features which make possible production of an approximate analysis without the use of analysed standards of any description. Practical tests have shown that, to a first approximation,

(i) the total intensity of the ion beams arising from the various isotopes of an element is directly proportional to the atomic concentration of that element in the sample, and is similar for all elements, irrespective of the nature of the matrix ;

(ii) the blackening of the photographic plate is a function of the intensity of the impinging ion beam and is independent of mass number ;

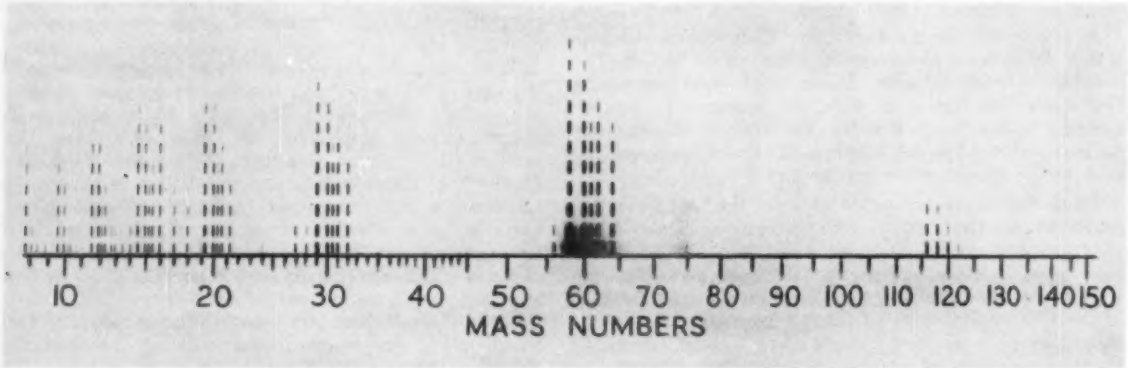


Fig. 8.—Mass spectra of a sample of high-purity nickel.

TABLE III.—VISUAL INTERPRETATION OF MASS SPECTRA : SPECIMEN SENSITIVITY TABLE

Spectra	Exposure Period	Sensitivity Value
1	1	7500
2	3	2500
3	10	750
4	30	250
5	100	75
6	300	25
7	10^3	7·5
8	3×10^3	2·5
9	10^4	0·75
10	3×10^4	0·25
11	10^5	0·075
12	3×10^5	0·025

(iii) the spark source excites the constituents of the sample in an exactly reproducible manner and, more specifically, the distribution of energy between the various stages of ionisation is constant ; and

(iv) no selective distillation of the various constituents of a sample occurs during excitation.

These remarkable features make it possible for an analysis to be carried out by visual comparison of the intensity of a line of an impurity in a long exposure with a line of the matrix (or any major constituent) in a short exposure. If both elements have only a single isotope and the two lines are of equal intensity, then the two contents are related by the ratio of the two exposures. If either element has more than one isotope, a simple correction based on the known isotopic abundance may be applied.

In practice, an accurately graded series of exposures (in terms of integrated ion-beam intensity) are recorded, based on a scale of three, with a relative intensity range of 1, 3, 10, 30 . . . . to 3×10^5. Mass spectra of a sample of high-purity nickel exposed in this way are shown in Fig. 8. Then, if an impurity line in the strongest exposure is equal in intensity to a line of the matrix element in the shortest exposure, the impurity content is $1/3 \times 10^5$ of the content of the matrix element, assuming that each element has only one isotope. The following routine method of visual plate evaluation has been evolved :

(1) From a knowledge of the dispersion of the instrument and the mass numbers of the major constituents of the sample, a mass-number scale is marked on the plate.

(2) An isotope line of the major element is identified and traced through successively weaker spectra until it is only just visible. (The point of disappearance varies slightly with the sensitivity of each photographic plate.) The number and exposure period of the particular spectrum are noted. From the atomic concentration of the matrix element, the isotopic abundance ratio, and the exposure period for the visual threshold, a " sensitivity value " is calculated for the particular plate. For example, in spectra of Nimonic 90 (a nickel-chromium-cobalt-base high-temperature alloy) isotope nickel 61 might be just visible in the first, minimum, exposure. The sensitivity value would be $7 \cdot 5 \times 10^3 \div$ (the exposure period). Proportionate sensitivity values are then acorded to each exposure, and the information is recorded in tabular form, as in Table III.

TABLE IV.—MASS SPECTOGRAPHIC ANALYSIS OF A COMMERCIAL STAINLESS STEEL
(Suppliers Analysis : Cr 18·75% ; Ni 8·44%)

Element	Content (atomic p.p.m.)	Element	Content (atomic p.p.m.)
Bi	0·05	Ga	30
Pb	20	Zn	240
W	4	Cu	500
Si	75	Co	200
Sn	100	Mn	3500
Ag	0·5	V	300
Mo	420	Ti	90
Nb	5	Ca	30
Zr	0·5	K	0·5
As	550	Na	0·5
Ge	3	B	12

The following elements were also determined (contents in atomic p.p.m.)

$\leqslant 0 \cdot 05$: Tl, Au, Ir, Re, Lu, Tm, Ho, Tb, Pr, Cs, I
$\leqslant 0 \cdot 10$: Pt, Os, Hf, Eu, La
$\leqslant 0 \cdot 15$: Er, Dy, Gd, Sm, In, Rh, Y, Rb, Sr
$\leqslant 0 \cdot 20$: Yb
$\leqslant 0 \cdot 25$: Hg, Nd
$\leqslant 0 \cdot 30$: Ba, Te
$\leqslant 0 \cdot 4$: Ce, Se
$\leqslant 0 \cdot 7$: Pd
$\leqslant 1 \cdot 00$: Cd
$\leqslant 1 \cdot 2$: Sr

(3) An appropriate isotope line for each of the required impurity elements is traced through successively weaker spectra until it virtually disappears, and the spectrum number and corresponding sensitivity value are obtained from the sensitivity table.

(4) The sensitivity value, multiplied by the reciprocal of the isotopic abundance, gives the impurity content, in (atomic) parts per million.

Analysis of standard samples of known composition has indicated that the maximum error with this technique should not exceed 200–300%, with a reproducibility (usually more important than absolute accuracy) of 30–50% of content. Many samples have now been analysed by this simple technique and check determinations by emission spectroscopy have confirmed its accuracy : a mass spectrometric analysis of a typical sample of stainless steel is given in Table IV. Under favourable circumstances, a lower limit of detection of 1 part in 10^8 may be achieved on an effective sample weight of only 1 mg.

An important factor affecting sensitivity is the maintenance of a really " hard " vacuum, particularly in the analyser section of the instrument. Four main pumping points are employed, each with its separate cold trap and oil-diffusion pump. The use of gold gaskets enables the spectrometer to be baked-out at temperatures up to 250° C. Pressures of 10^{-8} mm. Hg. are continuously and readily maintained : loading of plates and specimen electrodes may be carried out without affecting the main vacuum.

Mass spectrometric analysis is comparitively slow—no more than two to four samples can be analysed per day, using visual interpretation of the spectra. Although it is likely that the output of work could be substantially increased by the use of a suitable recording microdensitometer, the technique is nevertheless slow, and, unlike emission and X-ray spectroscopy, is not yet suitable for routine operation.

The two techniques of mass and X-ray spectroscopy are in fact direct opposites in their main features—mass spectroscopy is extremely sensitive, of comparitively low accuracy, and slow : X-ray fluorescence spectroscopy is relatively insensitive, very precise, and rapid. These two new techniques are, however, to some considerable extent complementary, and, coupled with emission

spectroscopy bring closer to realisation the possibility of carrying out a truly complete analysis by purely physical methods.

Acknowledgment

The author is indebted to The Mond Nickel Co., Ltd., for permission to publish this paper.

Rapid Estimation of Copper in Type Metals and Lead-Base Babbits

By James Brinn

COPPER is an undesirable impurity in type metal such as electrotype, linotype and stereotype, and is limited to 0·05%. In lead-base babbits a higher copper content can be tolerated but at the sacrifice of fluidity. The copper forms an inter-metallic compound with part of the tin, and, since this compound has a lower density and a much higher melting point than the lead-base alloy, it rises to the top and forms a dross, which impairs the fluidity of the alloy.

Both manufacturers and users are therefore interested in a quick and reasonably accurate check for copper content. A method previously described[1] is not applicable for such small copper contents, but using the following colorimetric method, employing rubeanic acid, an experienced chemist can make a copper determination in 15 minutes or less. Rubeanic acid for the determination of a small amount of copper in metals and biological samples has been described in the literature.[2]

Solutions

Gum Arabic Solution.—Add 5 g. gum arabic slowly under stirring to 125 ml. hot distilled water and allow to simmer for 30 minutes. Do not allow to boil since it may boil over. Cool. Add with stirring 125 ml. glycerin and keep well stoppered in refrigerator. This will keep at least 3 months.

Rubeanic Acid Solution.—Dissolve 500 mg. rubeanic acid (also called dithio-oxamid) into 150 ml. 95% ethyl alcohol, and keep well stoppered in refrigerator. This solution also keeps over three months.

Procedure

Dissolve a 1 g. sample in 7 ml. concentrated sulphuric acid in a small (125 ml) Erlenmeyer flask (Pyrex type or, still better, Vycor high silica type). Heat until precipitate is white or light grey. Cool. Add carefully 10 ml. distilled water and stir with a glass rod, then add 5 ml. concentrated hydrochloric acid. Heat and boil until precipitate turns white. Cool. Add with mixing 30 ml. distilled water, then concentrated ammonia until a litmus paper turns blue (from 12 to 18 ml. will be found sufficient). Then add glacial acetic acid until the litmus paper turns red. Now the solution is buffered and has the correct acidity for development of the colour. Pour the well mixed solution into a 100 ml. glass-stoppered measuring cylinder. Pour 5 ml. gum arabic solution and 4 ml. rubeanic solution into the Erlenmeyer, shake and then pour into the cylinder, then rinse out the Erlenmeyer with 5 to 10 ml. distilled water and pour that into the cylinder. Fill up to mark with distilled water, mix well and allow to settle. Then pour through a dry No. 31 Whatman filter into a dry colorimeter tube and measure at 650 mμ. Make up a calibration curve using samples with known copper content.

There may be objections raised to this method, but its accuracy is reasonable and above all it is rapid. This is important to the manufacturer of type metals, who wants to know as soon as possible if his metal is up to specification or if he has to refine it. Naturally, additional refining means additional cost.

1 *Metallurgia*, 1958, **59**, 105.
2 *American Foundryman*, 1951, **20** (5), 43; and *Analytical Chemistry*, 1960, **32**, 547.

Low-Friction Tin-Nickel Plating

THE advantages of tin-nickel plating were demonstrated on the Tin Research Institute stand at the Corrosion and Metal Finishing Exhibition last month. The exhibits included a chute down which pieces of brass, phosphor-bronze, steel, and tin-nickel plated brass were allowed to slide, the object being to show the qualities possessed by tin-nickel plating for reducing friction. No matter in which order the pieces were placed on the chute, that plated with tin-nickel invariably reached the bottom first. The importance of this non-friction plating is shown by the fact that one leading watch manufacturer has proved that watches with tin-nickel plated components now continue to go without re-winding for 36 hours, against the normal 30 hours. Manufacturers of trombones have found that to coat the slides with tin-nickel plating substantially reduces the amount of friction and so provides a better instrument.

These are but two instances which demonstrate the considerable value of tin-nickel plating in the field of friction. Tin-nickel plating is also an excellent means of preventing corrosion. Its properties and behaviour are quite different from those of its constituent metals: the tin and the nickel form an intermetallic compound, and it is this fact which gives electroplated tin-nickel alloy its unique qualities as a non-tarnishing protective coating and as a highly decorative finish.

Rented Instrumentation

SOUTHERN INSTRUMENTS, LTD., are now able to assist industry by introducing a new scheme which enables comprehensive electronic instrumentation to be acquired on a rental basis. The scheme is simple and provides an inexpensive means of obtaining equipment when it is most needed. During the hire period instruments are serviced and maintained free of charge. The equipment on hire may be purchased at any time after the first six months' rental, and its purchase price takes into consideration a proportion of the rents already paid. The scheme is operated by Southern Instruments' associated company Instrument Rentals, Ltd.

HALE AND HALE (TIPTON) LTD

(Producers of Fine Blackheart Malleable Iron)

MR. R. C. LEPPINGTON ON IMPROVED CURRENT TRENDS

The 24th annual general meeting of Hale and Hale (Tipton) Limited was held on December 21 at Dudley, Mr. R. C. Leppington (the chairman) presiding.

The following is an extract from his circulated statement :—

Although this is our Golden Jubilee year, I have to report that trading has been difficult, for despite a steady increase in business during the early part of the year, we suffered from selling prices which were too low, but these, I am pleased to say, have now been adjusted. The order book is quite healthy, and given fair trading conditions, the current year should produce improved results.

During the year under consideration we ceased production altogether from the open hearth furnace, having completed the installation of the rotary furnace bay. Further, the new mechanised moulding plant has now been completed.

Your Directors considered it advisable to make these changes in the shortest possible time, but production losses were inevitable during the changeover. The new plant only came into operation halfway through the trading year, during which period little benefit was felt. The new melting plant is now producing a first class material which is being absorbed by the extended mechanised plant.

The benefit of this capital expenditure is beginning to accrue at an increasing rate.

Our customers are drawn from all branches of the engineering industry ; we do substantial business with the motor trade, but the major portion of this is concerned with castings for the heavy commercial vehicle industry, and very little with the private car trade.

New outlets for our products are always being pursued and prospects generally are very promising.

SUBSIDIARIES

Unfortunately, the Subsidiary Companies have had a bad year, with the exception of Hale Enamellers Limited, which Company has done well, and at present is in a favourable position both as regards production and order book ; J. & J. Whitehouse (Tipton) Limited has also continued to make a useful profit.

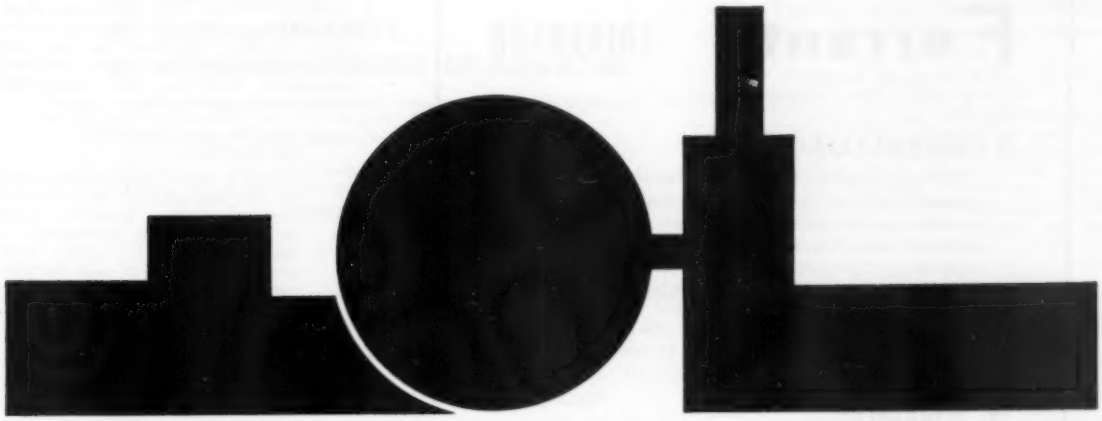
As regards Chatwins Limited, this Company's position has been most disappointing, the result regrettably only underlining what I had to say last year regarding the shrinking demand for solid fuel appliances. However, steps are already in hand which I hope will strengthen this Company's trading.

Turning to J. Wakefield & Sons, Limited, as you know from press reports, the unfortunate publicity given to Oil Heaters generally closed up completely any sales of these products from last December, with the consequence that this subsidiary made a loss for the year. Sales of its convector heaters have, I am pleased to say, recommenced, but not to any large extent. These products now carry the official "Kite" mark showing that they have passed the very stringent test imposed by the British Standards Institute on all Oil Heaters being manufactured and sold in the United Kingdom. Arrangements are already well in hand to diversify this Company's activities in the future.

After reviewing the financial results for the year, the Chairman commented on future prospects, and said :—

You may be assured that vigorous efforts are being made to produce a better result next year, more in keeping with the underlying strength and reputation of your Company.

The report was adopted, and the total dividend of 20% approved.



U.K.A.E.A. DOUNREAY

EXPERIMENTAL REACTOR ESTABLISHMENT

stands on the coast of Caithness, 9 miles from the thriving market town of Thurso. This ancient burgh has doubled in size in recent years with a corresponding growth of modern amenities. Staff are housed on the Authority's housing estate or, if single, in a comfortable hostel, and there are excellent opportunities for a wide variety of social activities and recreations. There are also good schooling facilities at Junior Secondary and Technical levels.

THERE ARE NOW OPPORTUNITIES AT DOUNREAY FOR

METALLURGISTS

for work involving the development of fuel elements for fast reactors for both Dounreay and future fast reactor systems. The research required embraces every aspect of fundamental and applied metallurgy of reactor materials.

These are progressive and pensionable posts, offering a real challenge and opportunity in new and expanding fields. The salary range is : £755—£2,460, according to qualifications and experience.

If you have a second class honours degree, or equivalent, in metallurgy, and, for the more senior posts, at least three years post graduate research experience, write, giving brief details to :—

THE PERSONNEL MANAGER, U.K.A.E.A., DOUNREAY E.R.E. THURSO, CAITHNESS

Please quote reference 163/126

SITUATIONS VACANT—*continued*

Ferranti EDINBURGH

wish to recruit

(1) METALLURGIST :

The work consists of a large number of problems on the materials used in the design and manufacture of high precision electro mechanical devices. A wide range of materials and processes is involved and a bias towards engineering or ceramics is desirable. In particular, a study of the technology of Beryllium will be eventually undertaken. Applicants should preferably have an honours degree in Metallurgy but candidates who are not graduates and have relevant experience will be considered. (Ref. MC/46).

(2) CHEMIST :

The work consists generally of the solution of all the problems of processes and materials used in the design and manufacture of electronic equipment. A wide range of materials and processes is involved but a knowledge of synthetic materials and analysis would be especially useful. (Ref. C/46).

In both cases the successful candidate will work in close association with teams of engineers and physicists engaged on development work. A staff position with membership of a pension scheme will be offered to the successful applicant. Please write giving details of qualifications and experience to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5, quoting the appropriate reference.

FOR SALE

Considerably below to-day's price

3½ TONS FERRO TUNGSTEN to the following approximate analysis :—

		82–83% W	
0·7	—	0·95%	C
0·001	—	0·005%	S
0·1	—	0·25%	Cu
0·2	—	0·5%	Si
0·2	—	0·4%	Mn
0·02	—	0·05%	P
0·01	—	0·07%	Sn

Enquiries to Box No. M.C. 103:

"Metallurgia," 31, King St. West, M/c 3.

Metallurgist (young qualified) required for Investment Casting Foundry in Midlands. Experience of steel investment casting essential. Good prospects and salary. Write, giving full details of age, qualifications, previous posts held etc., to Box No. MC 104 " Metallurgia," 31 King Street West, Manchester 3.

SANGAMO WESTON, LTD. require an Assistant for the Metallurgical Section of their Engineering Department. Duties will include spectrographical analysis and X-ray. Applicants should write giving full details of their training and experience to the Personnel Manager, Sangamo Weston Ltd., Cambridge Road, Enfield, Middx.

SITUATIONS VACANT—*continued*

A rapidly growing Company manufacturing Industrial Furnaces for firing of Ceramic Products, for batch heat-treatment of heavy metal fabrications, and for other, similar, functions in the high temperature field, require the following additional staff for their immediate expansion programme :—

(a) SALES—AND PROJECT ENGINEER

This is a senior appointment which covers responsibility for visits following customer enquiries (home and overseas), for preparation of specifications, and contract documentation, and it also includes general market development.

(b) RESEARCH AND DEVELOPMENT ENGINEER

This post cover responsibility for all research into existing and future processing applications for the Company's range of furnaces, especially in the Ceramic, Refractory, and Metallurgical fields. It also covers responsibility for the design and development work to produce new models for specialised applications. Testing of performance on the Company's installations is also included.

(c) ASSISTANT WORKS MANAGER

The man selected for this post will be the Deputy to the Works Director for all three sections (electrical. structural and refractory lining), He will also take charge of erection work and commissioning of furnaces at customers' factories (home and abroad).

All three vacancies call for men of sound theoretical training in engineering (either electrical or mechanical), preferably with some knowledge of refractories. They should have good practical experience in the construction and/or the operation of furnaces of this type. An age range of 28 to 42 years is preferred. Good salaries will be paid for these interesting appointments and there is ample opportunity of growing with the Company.

Apply in first instance to :—

A. G. HAYEK & PARTNERS LTD.,
Management Consultants and Industrial Engineers,
Federation House, Stoke-on-Trent.

giving fullest particulars of theoretical training, practical experience and salary requirements. Candidates' names will NOT be disclosed to client before first interview.

METALLOGRAPHIC MOUNTING MEDIUM

N.H.P. Mounting Plastic, a cold-curing acrylic resin, permits the rapid mounting of metallographic specimens without the aid of heat or pressure.

It calls for the minimum of equipment and skilled attention and yet gives a close, tight mount, capable of a high degree of edge preparation.

Used routinely by many leading manufacturers. Full details on request to the makers: NORTH HILL PLASTICS, LTD. MANLEY COURT, LONDON, N.16.

CLASSIFIED ADVERTISEMENTS

SITUATIONS VACANT—*continued*

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- **METALLURGISTS**
- **GENERAL SCIENCE GRADUATES**

We invite applications from Graduates to fill several vacancies in our Materials Department. These posts offer varied and interesting work in a wide range of subjects including :—

(i) The improvement of the oxidation resistance of graphite.
(ii) Application of Plasma Jets.
(iii) Thermal Shock Resistance of Materials.
(iv) Research and Development on Special Ceramics.

Please apply in writing in the first instance to:—

Personnel Department,
Hawker Siddeley Nuclear Power Co. Ltd.,
Sutton Lane, Langley, Bucks.

BICC

METALLURGISTS are required for the Shepherds Bush Research Laboratories of British Insulated Callender's Cables Limited for work on fabrication processes and properties of a wide variety of materials used in the electrical industry. Applicants should have a minimum qualification of L.I.M. and preferably two to three years laboratory experience.

The appointment would be to the Permanent and Pensionable Staff of the Company after a short probationary period. Good working conditions and social amenities.

Applications should be made to Personnel Officer, BICC Ltd., 38, Wood Lane, London, W.12.

METALLURGISTS

Two positions of responsibility are vacant in the Metallurgy Department of the recently established Group Research and Development laboratories of Associated Engineering Ltd.

SENIOR METALLURGIST

Age 28-35 years, initial salary £1,250-1,750

RESEARCH METALLURGIST

(Melting & Casting). Age 23-30 years, initial salary £850-1,350.

Candidates for the senior position should be University-trained physical metallurgists, with at least six years post-graduate experience relevant to work on the development and evaluation of new materials and shaping processes. Experience of the main analytical tools of the profession is essential and some knowledge of X-ray diffraction, electron microscopy and high temperature optical microscopy will be an advantage.

Candidates for the second position must be capable of supervising a small section concerned with melting and casting techniques, including vacuum melting, precision casting, die casting, inoculation, furnace technology etc. A University degree is desirable, together with some years experience of foundry technology, preferably non-ferrous.

Applications giving full details and quoting Reference JAR, should be addressed to, Associated Engineering Ltd., Cawston, Rugby, Warwickshire.

ROYAL TECHNICAL COLLEGE, SALFORD

DEPARTMENT OF MECHANICAL ENGINEERING LECTURESHIPS IN METALLURGY

Applications are invited for two appointments from persons having an Honours Degree in Metallurgy and experience in research in industry or in a University or College of Advanced Technology. For one of the appointments a special knowledge of welding or modern foundry practice would be an advantage. The persons appointed will teach metallurgical subjects and will be required and encouraged to carry out research and to assist in the development of a strong metallurgical research group in the College, for which good facilities are being provided

The salary scale for Lecturer is £1,350 rising to £1,550 per annum. Above this grade there are Senior Lectureships with a salary scale of £1,550 to £1,750. The successful candidate may be considered for such a post at a later date.

Further particulars and forms of application may be obtained from the Registrar, Royal Technical College, Salford, 5, Lancs., to whom applications should be returned by 14th January, 1961.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

DEPARTMENT OF APPLIED PHYSICS

Short Course on

"RECENT ADVANCES IN NON-DESTRUCTIVE TESTING"

23rd-24th February, 1961

A short course for physicists and engineers will be held on Thursday and Friday, 23rd and 24th February, 1961, and will include the following topics :— Radiography, Internal Friction, Ultrasonics, Eddy Currents, Surface Crack Detectors, Electromagnetic Methods of Quality Control, Fluoroscopy and Economics.

Fee : £1 2s. 0d.

Full particulars and forms of application from the Head of the Department of Applied Physics, Lanchester College of Technology, Priory Street, Coventry.

SITUATIONS VACANT—*continued*

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

(A constituent College of the University of Wales).

Applications are invited for the post of ASSISTANT LECTURER or LECTURER in the DEPARTMENT OF METALLURGY from the 1st April, 1961. Six copies of applications, containing the names of three referees, should be sent to the Registrar, University College, Cathays Park, Cardiff, from whom further particulars may be obtained, not later than February 6th, 1961.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

Course on

MODERN TRENDS IN THE THEORY AND PRACTICE OF ELECTROPLATING

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